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Towards a sustainable framework for electric vehicles fleet management by the public transport operator in Brasov city

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Abstract: *The paper proposes a holistic model for the management of the electric vehicle fleet used by Brasov's public transport operator. The principles that lead to the model of this complex framework, as well as the integrated components, the functionalities and the interactions between components are aspects treated in the paper. The operational optimization is implemented in respect of full Life Cycle Assessment point of view regarding the fleet and, at the same time, it considers the improvement of the overall energy efficiency for each system component. An important aspect is also emphasized herein, respectively, how the framework allows the smooth aggregation of internal functionalities such as the charging of vehicles' batteries and generation of electric energy based of renewable energy sources (RES, such as solar). It also includes the distribution power network characteristics and constraints. The potential for the improvement of the operation that results in the usage of fleet management is emphasized herein, as well as the future roadmap for such a system.*

Keywords: *sustainable transport, electric vehicles, fleet management, life cycle assessment*

1. INTRODUCTION

The transition from classical transport technologies to electrical ones is undeniable. The main reasons are related to the need to significantly reduce the eco-footprint of these services and the depletion of fossil fuels reserves. Especially in urban areas, the air and water pollution are relevant and transport activities represent an important contributor. The transition to electric technologies [1,2] is not easy to achieve as it requires significant efforts in research, technology development and innovation in order to assure that the quality of life and human health are not affected.

The paper provides an analysis of the changes that will be generated by this transition in a city like Brasov, where great efforts have been made in order to modify a considerable percentage of public transport fleet [3,4] from classical to electrical. Significant challenges are related to this transition, such as: how it should be managed and how it should be made sustainable.

Moreover, this paper proposes a framework for the management of this updated public transport system, emphasizing the main components, their role and the positive and negative aspects brought by them. Some solutions to overcome the difficulties that can result from this transition are proposed and investigated herein. The implementation will follow this stage of system analysis and thus permit a smooth transition. The main problems of this transition are related to the technological limitations related to battery technologies [3,5], energy efficiency of the power grid operation [6] and risks related to the security of operations. The later result from the deficiency of safe communication between system components [7,8] and are also related to the public acceptance of this new system. An important factor that can smoothen this transition could be the development in parallel with the public transportation system of the local energy generation based on renewable sources of electric power (RES). The aggregation and integration of these two systems into an efficient one is a must for the systems' development.

The aim of this paper consists in the description of the proposed holistic model, which is based on overall energy efficiency criteria and the Life Cycle Assessment (LCA) of public transport services in Brasov city. The emphasis is on the main system's components and their role, with positive effects and weaknesses, the technological challenges and the effects regarding the improvement of system operation. The objectives of this paper are related to the performance analysis of the monitoring system with its two components, the fleet parameter monitoring and the correlation and optimization of the vehicle charging operations. This includes the state of the distribution grid and the generation of electric energy based on RES. A secondary goal consists in the proposal of a model that will be developed for the system operation optimization. Another goal regards the effects of the proposed framework in the improvement of preventive maintenance of the electric vehicle fleet, with a focus on combating the process of accelerated aging in batteries. Finally, the emphasis will be on the mechanism that will improve the sustainability of the systems' implementation as a result of better usage of existing resources and appropriate application of technological changes to the management system.

The conclusion highlights the importance of the proposed solution and at the same time the innovative aspects resulting from the implementation.

2. STRUCTURE OF THE HOLISTIC MANAGEMENT SYSTEM FOR ELECTRIC VEHICLES FLEET

The necessity to create a holistic solution for the electric vehicles fleet is a result of the complex tasks assumed by the management system and also as a result of the new sensitive technologies applied, especially on mobile storage systems. The later permit the safe and adequate operation in urban environment. The management system on the one side, implements the monitoring in real time of each system's component and on the other side, runs the appropriate models for these components assuring the optimized control with benefic effects in exploitation and the prevention of urban air pollution. The proposed structure is illustrated in Figure 1. The data provided by the monitoring system is transmitted with an adequate sampling rate as a function of signal acquisition

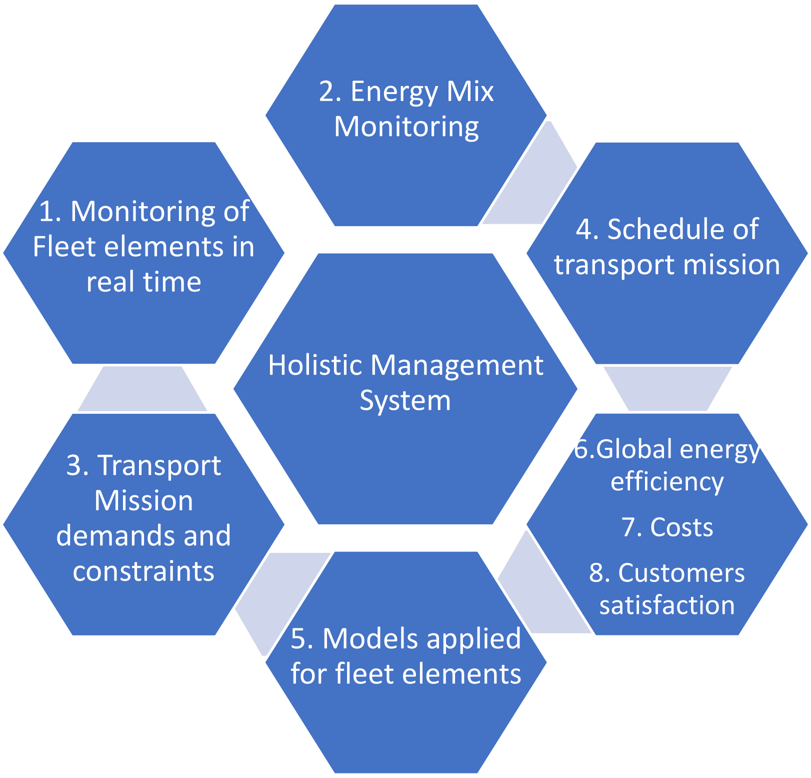

Figure 1: Holistic management system for optimization of public transport system for Brasov city transport operator

as it is necessary in system control. A detailed image of signals monitored is provided in Figure 2. This corresponds to the sub-system integrated on each vehicle part of the public transport system.

1. The GIS data is related to the geographical position of the vehicle and is acquired every 10ms with a resolution that depends on the satellites' visibility. Also, the same system provides the vehicle speed and correlates this data with the corresponding map. Sensors for the passenger number are mounted inside each vehicle and data about this parameter together with the accounting/ticketing will be immediately correlated after departure from each station. The vehicular sensors that monitor the current consumed by electric motors, the air conditioning system and the auxiliary vehicles' components are also used in data acquisition. The sampling rate could reach 100Hz. The sub-system will correlate this data to other data such as external vehicle temperature, position of vehicle upon its transport mission and other related data such as road slope for example. The resolution of the data acquisition system found in the vehicles will be improved with 12 bits for every signal acquired. In the case of vehicles batteries' temperature and the State of Charge (SoC) data can reach 16 bits resolution. The main targeted technology that is considered herein is Internet of Things (IoT) [3]. Obviously, this data can be independently measured or it can be transferred from the operational Battery Management System.
2. From the power grid side, necessary data about the current stage of the regional power grid and also regarding the RAT generators, based on solar and wind, can be acquired. These statistics are assembled into the Energy Mix metering component of the holistic management system.

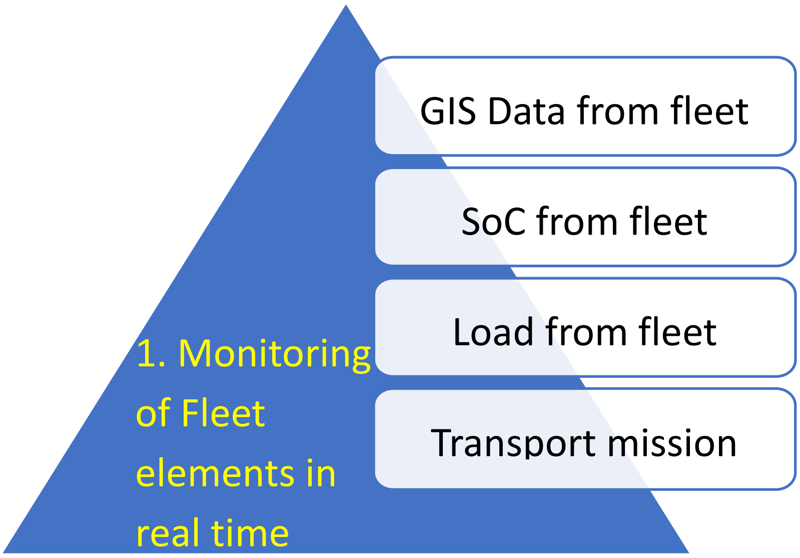

Figure 2: Signals acquired in real time from each data acquisition vehicular system (communication wireless)

Data will be provided with a rational sampling rate, such as 1 sample/second, and it will illustrate the energy mix introduced into the system's model. This will allow the optimization of fleet operations. If RAT will be accepted as an eligible operator on the energy spot market, then these data will partially be the result of the commercial activity of RAT on this market. Another interface is necessary to provide the current weather data for the region where this system will operate. The sampling rate should be around 1 to 5 minutes.

3. Related to the transport mission of the fleets' vehicles [4] this component will be designed by the RAT personnel prior to the operation period and will be updated by the holistic management system during operation with information of public interest. For example, customers can acquire the desired information by multiple means, such as display panels placed in the stations, on the operators' internet site etc. The data update rate could be again between 1 to 5 minutes. Also, data about the traffic status and its management in the urban area where the fleet is operating will be transferred from quasi-autonomic urban-traffic management systems periodically. The transfer rate with all available data should be around 1 record/minute.

For all data interchanged between the systems' components a critical issue is related to the preservation of data accuracy and also its security. The intrusion avoidance function also must be implemented and it consists in using strong cryptographic methods, redundancy of communication channels in order to interchange data and accurate and adequate sampling of data bases or records. The block chain technologies are to be studied as this technology is adequate for the scope of the desired system. For all the data bases of the system a special attention will be paid to the synchronization of records, using a unique time related clock by Universal Time Clock (UTC) provided by the GPS system. For massive amounts of data, a special attention is to be paid for duplicate records at the sampling moment so that all the data will be used by the system. All the interfaces must be standardized and clearly defined as structures and work flow procedures too.

4. The scheduling that integrates the overall transport missions at any moment will be incrementally developed. Initially, based on heuristic decisions the program will be issued. During the operational phase of the system the initial schedule will be dynamically updated, the sampling period will correspond to a period equal to or greater than the maximum travel time of vehicles. At the same time, any modification of the schedule will be deployed to the display units and also on the internet in order to notify the potential customers about these modifications. An appropriate communication and updating system will be developed with respect to the data security transfer principles.

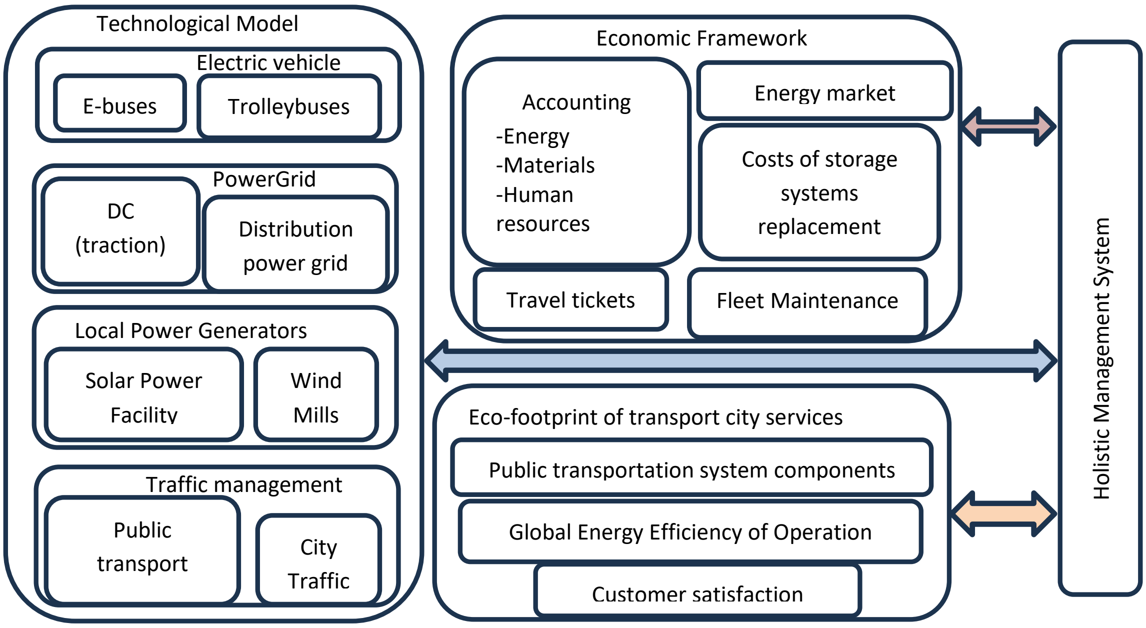

Figure 3: Twin Holistic Management System for optimization fleet Operation in Brasov city

The Holistic Management System Model integrates several components will act as the support for the simulation program. In fact, the paper proposed a twin holistic fleet management system and the included software components are shown in Figure 3.

Related to the models that the system will use, these are classified as follows:

i. Technological models that will illustrate the power flow in the system, sources, consumers, losses on the power flow transfer pathways and constraints related to all of these;
ii. Economic models that will consider all the costs related to the operation of the fleet;
iii. Model based on LCA related to each system's components:
    a. Models that consider the quota of pollution from each system's components;
    b. Model for forecasting the transport mission for short and medium term (hourly and daily);

c. Customer satisfaction model that will consider the trends in the evolution of public transport system. Obviously, this model will consider the seasonal variations related to travelers, the weather conditions and other factors that influence the customer habits. The trend slope will be an essential indicator for improving dynamically the operation of RAT fleet;
d. Model that pays special attention to the exceptions that can appear during systems' operation. These will be classified and the causes of events will be used to identify that particular event that generates dysfunctionalities;
e. A costs model of all systems' components is to be implemented in order to emphasize the global economic efficiency of the system.

3. CONCLUSIONS

The complexity of the tackled problem requires a large commitment for the development of each component, the standardization of communication and the security of the data transfer. The reliability and the resilience of the proposed programs will be addressed in for the next stage of this project. The current study was made as a structural investigation, taking in consideration almost all systems' components. The main challenges have been raised within the proposed implementations, requiring the use of standard and structured components for the programming modules. Also, interfaces and elements are mandatory in order to preserve the coherence, reliability, scalability and predictability of the system in operation.

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