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SMART SOLUTIONS FOR SMART CITIES - VETSOL (Application of renewable resources in urban areas)

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Abstract
This paper introduces VETSOL, an innovative energy island designed to promote self-sustainability in smart cities by generating the necessary energy for lighting, signaling, monitoring, and management. VETSOL supports the trend of sustainable urban development by generating renewable energy for various city functions. The paper will present VETSOL's capabilities in generating energy through solar panels and wind generators, enabling efficient lighting of intersections and road sections, supporting light signaling, and providing video surveillance for main highways and intersections. Additionally, VETSOL facilitates the distribution of information necessary for optimizing traffic flow in smart cities.

Key words: *smart cities, green energy, traffic, solar panels, wind generators.*

1. Introduction

This work includes concrete practical solutions applicable in modern urban environments. When a smart city is mentioned, most of the stories usually come down to concepts, but not specific solutions or technical improvements. The application of new technologies supports a structure that enables the collection and processing of a large amount of information. Smart solutions usually imply a more rational use of resources or their new application to improve the quality of life in smart cities. Assessment of the level of development and quality of solutions is usually obtained by comparing living conditions in individual cities.

By recognizing unused potentials, we give a new use value to structures and constructions that are present in cities, and can serve for a more rational and quality life of people in the city. The specific application of renewable energy sources with the generation and use of energy in the immediate vicinity of the source enters the spheres of smart use of energy, reduction of environmental pollution, support for other systems that give the epithet "smart" to such cities. The harmony of the use of

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wind energy, the sun and alternative energy sources (air masses triggered by the movement of vehicles in traffic) increases the utilization of hybrid resources that will be presented in the work. Here, solutions are considered and offered that use available components with a superstructure that enables the realization of energy islands. The energy generated is used for lighting, signaling, powering communication and monitoring units, and even charging electric vehicles (E-bike, E-scooter, E-taxi, E-bus, future E-aviotaxi).

Regardless of which aspect of life we touch, it has consequences in many independent areas, and the ultimate consequence is raising the quality of life of citizens. Energy islands represent new solutions that increase security in large centers in urban areas, and at the same time support the application of technologies to obtain configurations and solutions characteristic of smart cities. The rationalization of the use of existing installations increases the energy efficiency, safety, and usability of structures and facilities located in smart, urban environments.

The technical solutions offered impact all domains that give the label "smart" urban environment: successful generation and rational use of energy, work without pollution in the immediate environment (Figure 1), awareness of the state of the environment, support for traffic control, supervision, and regulation.

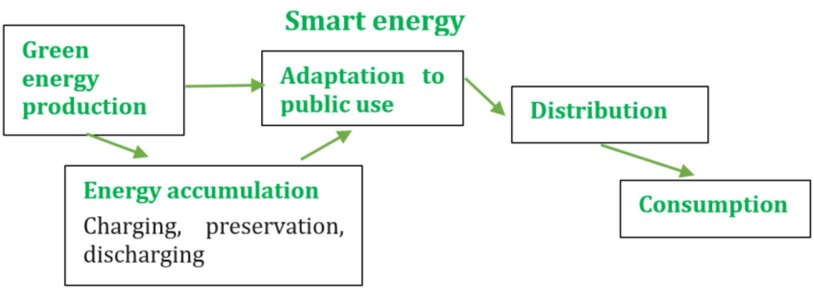

Figure 1. Smart energy structure

Today, when we talk about smart energy, we usually consider the production, accumulation, distribution and consumption of energy with minimal negative impact on people and their environment. Green energy implies the use of renewable sources such as: solar energy, wind energy, energy obtained from biomass. It is also known that the contribution to the final energy balance is variable and depends on which source we are looking at, so in addition to the possibility of obtaining electricity, a significant factor is related to its temporary accumulation. The increase in capacity and the reduction of losses during charging, preserving and discharging of the accumulator significantly affect the rationality of the energy system. There are several options for energy storage, but the most commonly considered are the use of chemical sources such as Li-ion and Na-ion batteries, but more and more people are pointing to the great potential that lies in the use of hydrogen in internal combustion units as well as in fuel cells. Both mechanical and thermal energy accumulators are in use. In urban areas, at least with existing solutions, chemical energy sources have proven to be the most practical.

2. Green energy production

Characteristic of our solution is the production of energy in the urban environment in the immediate surroundings where the consumers themselves are located. This enables rational use of energy without transmission losses. VETSOL combines several different devices that use several forms of renewable energy sources in parallel.

VETSOL 1 (Figure 2) – Vertical wind turbine with solar air deflectors, solar coating over the turbine blades and the option of direct energy conversion into a usable form or temporary storage options.

Air deflectors concentrate the movement of air masses (from the wind or driven by the movement of vehicles) towards the active part of the wind turbine, which increases the efficiency of the device. At the same time, we use the air deflectors as solar panels with two faces, so they are also used for direct conversion of solar energy into electricity. Flexible, high-efficiency, photovoltaic panels are used to cover the turbine blades so that part is also a photovoltaic panel. Using slip rings, the generated energy is fed to the charger or electrical converter. Placement of the device is planned on traffic islands.

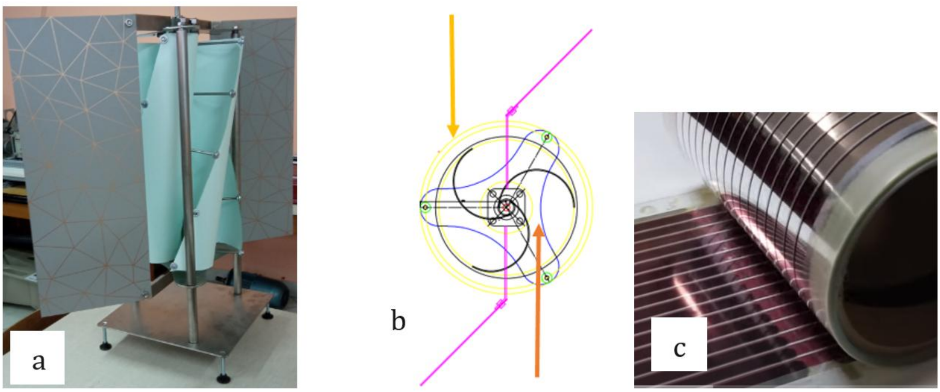

Figure 2. VETSOL 1 a. physical layout, b. traffic-driven air routing, and c. flexible, high-efficiency photovoltaic panel.

VETSOL 2 (Figure 3) – Horizontal, helical wind turbine mounted on a modified roadside guardrail. The protective fence is an adapted construction that carries a flexible, high-efficiency, photovoltaic foil, so it itself represents a photovoltaic panel. The segments of the fence were reconstructed in order to obtain a larger active surface for the photovoltaic system, and at the same time to obtain an air deflector for the wind turbine that uses wind energy and the energy of the masses set in motion by the movement of traffic. LED lighting segments are placed on the segments of the protective fence, but in such a way that they do not dazzle the drivers, and enable good lighting of certain sections of the road. The light is right next to the road, so it is much more effective lighting than the components placed on high candelabras.

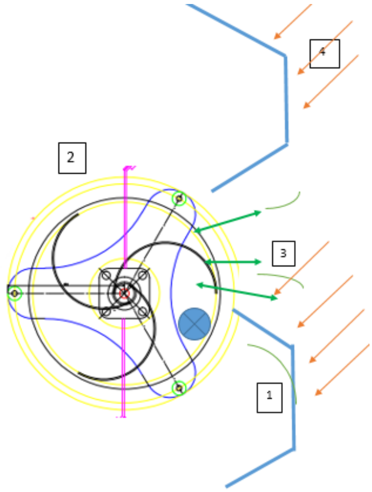

Figure 3. VETSOL 2 - 1. Protective fence at the same time solar panel, air deflector and LED lighting support 2. Spiral wind turbine with axis in horizontal position 3. Air flow 4. Sun rays

What is recognizable within the analyzed solution is the simultaneous use of solar energy, wind energy and energy of air masses set in motion by vehicle movement.

3. Energy accumulation

Today, when we talk about smart energy, we usually consider the production, accumulation, distribution and consumption of energy with minimal negative impact on people and their environment. Green energy implies the use of renewable sources such as: solar energy, wind energy, energy obtained from biomass. It is also known that the contribution to the final energy balance is variable and depends on which source we are looking at, so in addition to the possibility of obtaining electricity, a significant factor is related to its temporary accumulation. The increase in capacity and the reduction of losses during charging, preserving and discharging of the accumulator significantly affect the rationality of the energy system. There are several options for energy storage (Figure 4), but the most commonly considered are the use of chemical sources such as Li-ion and Na-ion batteries, but more and more people are pointing to the great potential that lies in the use of hydrogen in internal combustion units as well as in fuel cells. Both mechanical and thermal energy accumulators are in use. In urban areas, at least with existing solutions, chemical energy sources have proven to be the most practical.

Usually, the minimum dimensions, costs and density of the accumulated energy decide which solution we will apply. All important attributes are respected by modern chemical sources, which, in addition to large capacity, also have the possibility of fast charging as well as a large number of working cycles without reducing or impairing the working characteristics. This area is also in great expansion and more and more rational and better solutions are constantly being found.

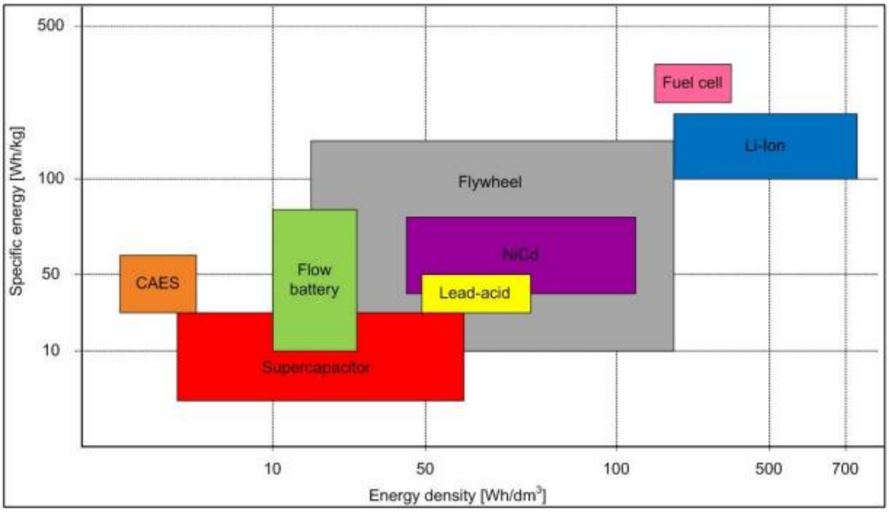

Figure 4. Different technologies for energy storage and its density

Usually, smart energy use means storage and rational use, and **smart charging** is also shown here on Figure 5.

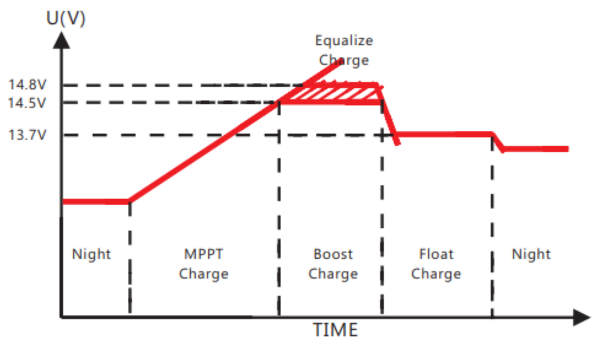

Figure 5. Smart charging - Magic series controller has a 4-stage battery charging algorithm for rapid, efficient, and safe battery charging.

MPPT Charge - In this stage, the battery voltage has not yet reached boost voltage and 100% of available solar power is used to recharge the battery.

Boost Charge - When the battery has recharged to the Boost voltage setpoint, constant-voltage regulation is used to prevent heating and excessive battery gassing.

Float Charge - After the Boost voltage stage, the controller will reduce the battery voltage to Float voltage setpoint. When the battery is fully recharged, there will be no more chemical reactions and all the charge current transmits into heat and gas at this time. Then the controller reduces the voltage to the floating stage, charging with a smaller voltage and current

Equalize Charge - Certain types of batteries benefit from periodic equalizing charge, which can stir the electrolyte, balance battery voltage and complete chemical reaction. Equalizing charge increases the battery voltage, higher than the standard complement voltage, which gasifies the battery electrolyte.

4. Adaptation to public use

Central inverters convert DC power from solar panels or DC accumulation to AC power that can be used by homes or businesses or can be connected to the grid. To maximize efficiency and improve reliability, manufacturers are beginning to seek innovations that cut costs, create smart grid features, and standardize monitoring and control interfaces (Mamadaminov, 2014). New solutions provides designers with high-quality and reliable components that save space without sacrificing power, including off-board power connectors, terminals and splices. DER inverters are continually evolving – newer systems have advanced features that are compatible with smart grids. In addition, DER inverters are being enhanced with sensors and monitoring tools for use as energy management centers. There has been much discussion about how to implement maximum power point tracking (MPPT) to achieve high system efficiency and smart functionality from the perspective of the power generation system. Later, however, the need for grid-supporting functions to realize ancillary services such as voltage regulation in addition to general functions began to be actively discussed. So-called "smart inverters" provide such ancillary services by offering flexible control of the active/reactive power of DERs (de Carvalho et al., 2020). On the other hand, current source inverters, which have been often used in PV interconnection, cannot operate without AC voltage generated by other generators connected to the grid. These inverters themselves generally do not generate voltage and follow the voltage on the grid side, so they are called grid-following (GFL) inverters. These GFL inverters have been used not only for PV but also for BESS interconnection. In many real-world implementations, wind power interconnection is also being considered, in which the AC generated is converted to DC and sent to the grid via a GFL-type inverter. Therefore, there is a concern that a large number of grid-following-type DER inverters will lead to a relative lack of inertia contributed by conventional power generation facilities on a grid scale. Thus, DER inverters that have a voltage source called grid-forming (GFM) inverters (Ducoin et al., 2023), which create such inertial forces and enable frequency control and voltage magnitude control, are being developed to provide even smarter functionality.

5. Energy distribution

The use of VETSOL devices is for the time being planned for the supply of devices related to traffic control and providing power supply:

1. The system for lighting road sections, intersections, toll plazas, rest areas,

2. The system for auxiliary signaling of displaced objects in relation to the distribution network,
3. The system for distributing data on traffic conditions (fog, congestion, works,...). Powering control circuits, sensors, but also microcomputer components as well as communication equipment,
4. Video surveillance system (cameras at intersections, toll plazas, control points),
5. Information systems at bus stops.
6. Supplying roadside advertising panels,
7. Charging and supporting new traffic surveillance drones,
8. All future installations that will be used in autonomous driving.

Additional options related to island operation, connection of distributed units or direct connection to the distribution network are considered. If there is no system for energy accumulation, then the use is limited, but at the same time we get a high degree of usefulness because all the produced energy is directed directly to the network, so we do not have the typical losses that occur when charging, storing and discharging the accumulation.

Accumulation enables better balancing due to the uneven period of generation and use of the necessary energy. We adapt the configuration of the system to the requirements of the environment.

6. Conclusion

VETSOL units support traffic flow in smart cities. The capacity, the number of units (devices) determines the possible application in selected environments. Installation of the device does not require a large space and is easily implemented in the existing traffic infrastructure.

The construction of the device enables operation in outdoor conditions. Adequate protection of all electrical and mechanical circuits is used. Rotating brushes are used for washing and maintenance of the panels that are placed on the protective fence, which are easily adapted to vehicles that are normally used for road maintenance and usually drive mobile lawn mowers through a special arm.

The return signal from the panel can be used to identify damage to the protective fence on a certain road section.

By using VETSOL devices, smart cities receive essential support that enables increased traffic safety, as well as help in the event of an emergency situation and the need for additional signaling or data storage and distribution to both traffic participants and services in charge of traffic regulation.

The use of VETSOL devices enables the expansion of the use of intelligent intersections.

Intelligent roads are roads equipped with technological tools that interact with the environment to enable safe and efficient traffic. An intelligent road system combines physical infrastructure (such as sensors and solar panels) with software infrastructure (such as artificial intelligence and data).

Figure 6. Intelligent road

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