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APPLICATION OF RENEWABLE ENERGY SOURCES IN TRAFFIC – BUS STATION AS A GREEN ENERGY ISLAND

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Abstract: The use of renewable energy sources in urban areas is becoming more common. Our design solution offers the possibility of supplying energy to fully electric buses at adapted stops, especially at the final stations (turning points). Adjusting the roof of the station enables the use of solar energy and wind energy with the possible expansion of the application of the road structure in order to increase energy capacities (protective fence as a linear energy block and sound protection of the settlement from traffic as an energy island). In addition to the good fit of the wind generator and the photovoltaic panel, their mutual harmony increases the overall efficiency of the entire system. The convenience of the turnpike is due to the longer stay of buses compared to other stops, so there is enough time to recharge the batteries, and at the same time, there is less influence of neighbouring buildings on the station installations on the periphery, so the use of renewable energy sources is better.
Keywords: renewable energy, electric bus charger, hybrid electric vehicle

INTRODUCTION

Many countries have green transport or green lines. The Nederland has been supplying the railways with renewable energy sources for a decade. This is an attempt to bring the production and consumption of energy as close as possible, and at the same time to point out that urban areas also have untapped potential.

The paper wants to point out solutions that can improve and facilitate the operations of carriers in the city. The necessary structure for the formation of e–bus chargers can be completely concentrated at bus stations, but road infrastructure can be also used as support (solar protective fence with wind generator, as well as a protective wall against traffic noise as energy support).

At the same time, they want to use all the developed potential for automatic connection and charging of the accumulators located in the bus (pantograph or increasingly successful wireless system for charging large batteries).

BUS STOP AS GREEN ENERGY ISLAND

The most common design of electric buses is with the accumulation of energy in electric form with the use of suitable high–capacity accumulators. It should be borne in mind that this category of vehicles is divided into BEV, PHEV and HEV electric vehicles as shown in Figure 1.

Regardless of which category of vehicles we want to support in the form of charging on the road route, we want it to be based on the use of renewable energy sources. Due to the significant power of such a charging system, a large active photovoltaic area supported by a hybrid solution with wind generators is required. The most favorable location for placing the equipment is at the central bus station, where there is the largest roof area on which the panned equipment can be placed. The second option is usually offered by turnpikes or the end stations of certain routes due to a slightly longer stay compared to standard stops.

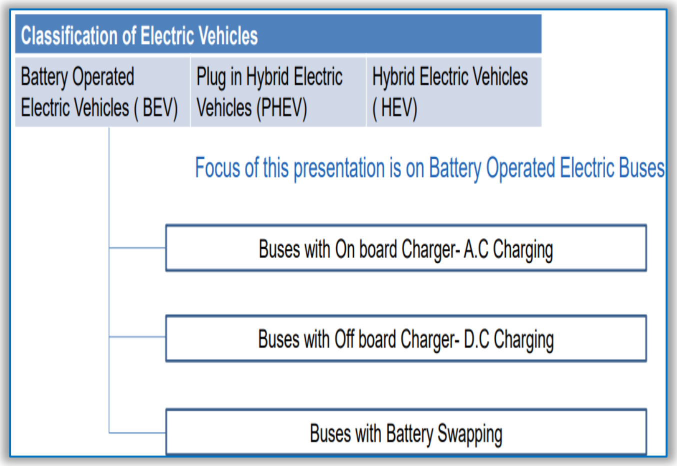


Figure 1. Battery operated Electric Buses

In this paper, three options are considered:

1. Constant charging of the station's energy wall from renewable energy sources with fast charging of the bus battery when it is in the station,
2. Charging of mobile replacement batteries where time does not limit the charging time but the battery replacement time (optional – battery trailer – Figure 2 [3]).
3. Using the trolley bus contact network to supplement electric buses.

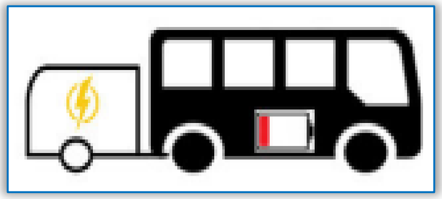


Figure 2. Accumulation and replenishment system in the form of a trailer

Modern buildings have a small slope of the roof, which is not the most favorable position either for using solar energy or for using wind energy. Table 1 shows how the slope of the roof affects the acceleration of air masses at its highest point – the ridge. Correction of the slope of the roof can be done with air deflectors, which also serve as photovoltaic panels and directly convert the energy of solar radiation into electricity.

Table 1. Wind gain depending on the slope of the roof

Roof slope	0^0	8^0	15^0	30^0	45^0	60^0
Wind acceleration	X 1.0	X 1.1	X 1.2	X 1.5	X 2.2	X 1.3

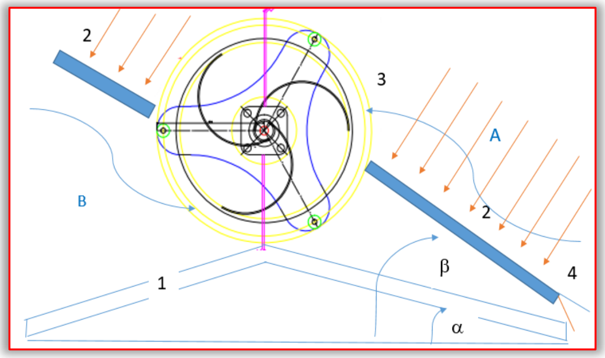


Figure 3. Hybrid power station – The roof of the bus stop
1–The roof of the bus stop; 2–Photovoltic cell; 3–Wind turbine [5]; 4–Blinds
A, B – Different wind directions; α– Roof slope; β – Photocell slope

The photovoltaic panel (Figure 3) directs and accelerates the air (table 1) increasing the efficiency of the wind turbine. Apart from directing the wind towards the drive part of the turbine, doubling the speed increases the power 8 times [equation 1]. A higher tilt of the fixed panel gives a higher utilization of the photovoltaic panel at our latitude.

$$P_{wind} = \frac{E_{kin}}{\Delta t} = Cp\frac{\Delta V \rho v^2}{2\Delta t} = Cp\frac{\rho A v^3}{2} \quad \text{[eq 1]}$$

$$C_p = \frac{2P_{wind}}{\rho A v^3} \quad \text{[eq2]}$$

v – wind speed, ρ – air density, A – covered area, Pwind – wind power, Cp – power factor

This study aims to optimize the shape of Savonius wind rotor to achieve highest C_p *[7]*.

The blades of the wind turbine are coated with high–efficiency photovoltaic foil to form an additional photovoltaic panel.

The entire structure forms a large photovoltaic panel with a wind–generator. If we use a spiral turbine, we use wind energy even when it blows sideways in relation to the object. Wind speed is measured with a Testo anemometer – Figure 4.

Figure 4. Testo Anemometer

E – bus supply system

With new technical solutions, more options enable the automatic connection of the E–bus and the powerful battery charger [11]:

- E–Bus stationary charging (wire connection – pantograph). ABB pantograph e–bus charging system [2] is shown in Figure 5. Different pantograph systems for e–bus – Figure 6.

Figure 5. ABB pantograph e–bus charging system

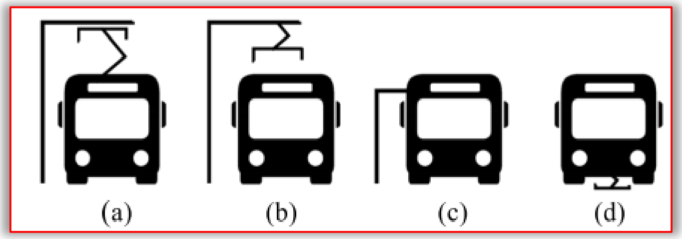


Figure 6. Different pantograph connection models and real configuration: (a) roof–mounted (b) inverted (c) horizontal (d) underbody. [13]

- E–Bus charging in motion (partial trolley bus) [9] – as it shown in Figure 7:

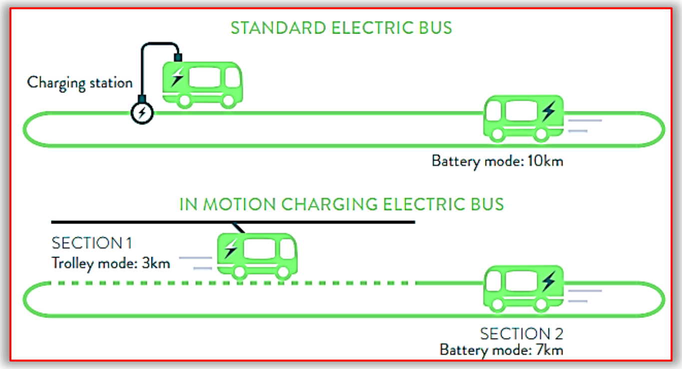


Figure 7. Stationary and charging in motion (wire option)

a) Possible bus connection on the tram's power line
b) Possible line supply from the "Green bus charger" [8]

- Green bus charger supplied from the turning point – station
- Online section supply from "Power WALL" – protection against traffic noise
- Online section supply from "Fence power structure" – off–road protective fence
- Energy islands in traffic – hybrid system photovoltaic panel and wind generator
  - E–Bus stationary charging (wireless charging) [13],
  - E–Bus charging in motion (wireless charging in motion) – Figure 8.

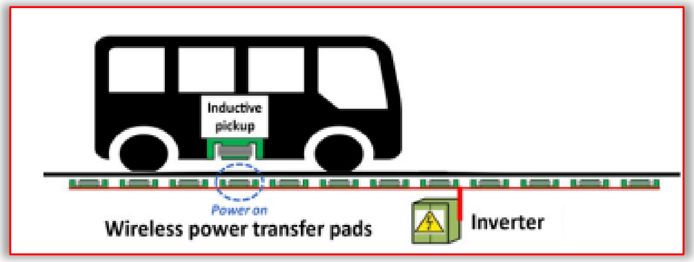


Figure 8. Wireless charging in motion

Wireless charging

Based on operating Techniques EVWCS (Electric Vehicle Wireless Charging System) [15] can be classified into four types:

- Capacitive Wireless Charging System (CWCS)
- Permanent Magnetic Gear Wireless Charging System (PMWC)
- Inductive Wireless Charging System (IWC) – Figure 9.
- Resonant Inductive Wireless Charging System (RIWC)

By using WCS EV's travelling range could be improved with the continuous charging of its battery while driving on roadways and highways. It reduces the need for large energy storage which further reduce the weight of the vehicle.

Position of Hybrid panels + Wind generators

When using hybrid panels to charge e–bus batteries, many options are usually provided:

- Installation of hybrid panels on administrative buildings and garages of the utility company in charge of transportation.
- Installation of hybrid panels on the main bus station and usually a large canopy.
- Installation of hybrid panels at the final bus stops due to longer bus stops for recharging – Figure 9. Savonius turbine is optimised for this purpose [6].

Figure 9. Photovoltaic canopy (bus station) with wind generators (turbine is a photovoltaic panel, too).

- Installation of a hybrid system (solar panel + wind generator) on protective fences against traffic noise.
- Installation of hybrid system components on the roadside guardrail – Figure 10.

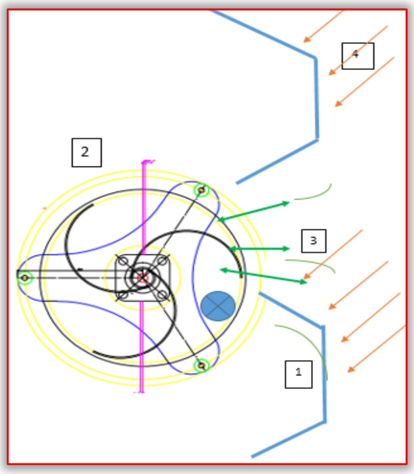


Figure 10. Roadside guardrail E– Wall
1–Roadside guardrail – photovoltaic panel, wind diverter, 2–Helical Savonius turbine [4]; 3–Alternating movement of air traffic masses; 4–The sun's rays are converted into electricity on the panel.

The system converts the energy of the sun, the energy of the wind and the energy of air masses of traffic into electrical energy.

- Installation of photovoltaic components and wind generators on traffic islands.
- Installation of photovoltaic components and wind generators on a typical bus station.

ANALYSIS OF WIND GENERATOR OPERATION (MODIFIED SAVONIUS)

The energy can be collected with the help of a helical Savonius turbine exposed to the wind flow that is accelerated due to the slope of the roof. Such wind turbines is more efficient and economical compare to conventional which are based upon natural wind energy.

Our turbine type is Mini: This type of wind turbine can produce electricity from 250 W to 1400 W. The standard of classification of wind turbines was regulated in IEC 61400 for large, medium and small wind turbines.

The performance improvement of a helical Savonius rotor is studied by using three dimensions CFD model & experimentally in the papers. Researches are carried out to study the influence of blade number, overlap ratio, helical angle, no. of stage and aspect ratio on the performance of helical Savonius rotors [17].

The Savonius turbine is usually used as a vertical shaft turbine [1], but here it is used with the shaft in a horizontal position. If we use a helical turbine, we use wind energy even when it blows sideways in relation to the object. Helical Savonius turbine with some variations is shown on Figure 11.

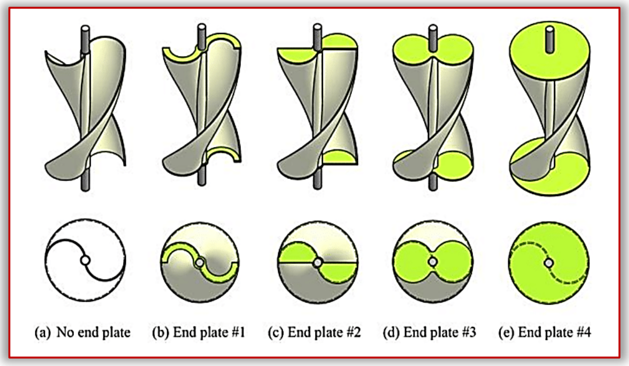
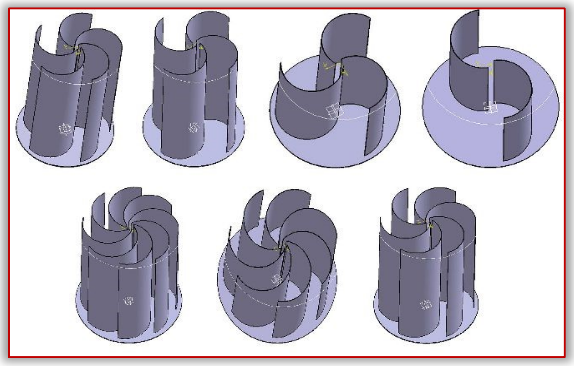


Figure 11. (a) Helical Savonius rotors at different twist angles



(b) Helical Savonius rotors with different number of blades

Advantages of usage this type of turbine:

- High output even at a low wind speed of 2.8 m/s (10 km/h)
- Strong wind gusts are easily managed and eliminates the need for complex adjustable blades
- The system does not require a shutdown even during a storm (other turbines are at shut down at wind speeds in excess of 24–27 m/s)
- Practically silent operation
- Constant uninterrupted output in high winds
- The system is robust, shows little wear, it is maintenance–free, has low operating costs and the mechanical structure is not complex
- Use of permanent magnet generators with long life and low–speed
- High uptime
- Extremely low starting torque and therefore good electromechanical conversion of the kinetic energy
- No special foundations are required, a simple bracing is in most cases sufficient. Easy installation on the ground, roof and wall mounted
- The use of advanced fiber composites ensures an ultra–lightweight construction with maximum strength and UV resistance and therefore high efficiencies
- Modular and highly flexible construction (equal part–modular principle). Individual components can be replaced at any time. A power increase via retrofitting is possible at any time
- The helical structure provides the wind with sufficient engagement surface at all times and at every angle of rotation
- Ultra–modern, rational, and cost–effective production
- Performance optimization using the latest power electronics
- Uniform rotary motion
- No mechanical losses, since the system operates without gearing (direct transmission)
- Extremely profitable due to low cost, easy installation, and maintenance–free operation with a virtually unlimited lifetime
- Excellent aerodynamic efficiency
- Superior optical effect
- Can be used as an advertising medium

ANALYSIS OF SOLAR PANEL PERFORMANCE

The economic viability of a power plant to harness solar energy mostly depends on the efficiency of solar panels. Investigations over the years show that solar panel efficiency significantly depends on the different meteorological parameters [16]. Therefore, there is an imminent need for a correlation explaining the relations between efficiency and different meteorological parameters. In this study, an effort has been made to analyze the effects of various meteorological parameters on efficiency and subsequently propose a correlation between them.

Figure 12 shows the measurement related to the power obtained from the solar panel, depending on the slope of the same. During most of the year, the maximum is observed at an angle between 35 and 45 degrees.

As we have covered before, the angle of the sun's rays change throughout the year, so the 'perfect angle' will change throughout the year [12]. The experimental solar panel efficiency was then determined by using the methodology listed below.

$$\eta_p = P_p/(A_p x I_p) \quad \text{[eq 3]}$$

Here, η_p is the solar panel efficiency, P_p is the power, A_p is the surface area of the panel, and I_p is the solar intensity. Here, the power of the solar panel is the product of voltage and current, which are measured with the help of a multimeter. Likewise, the solar intensity is measured with the help of a solar power meter – Figure 13.

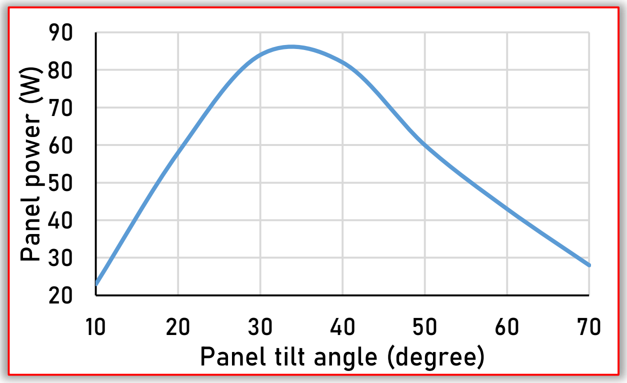


Figure 12. The influence of slope on the usefulness of the panel

Figure 13. Solar power meter TMP206

ACCUMULATION OF ENERGY

Usually, the contributions of energy from renewable sources are not aigned with the current needs of consumers, so the possibility of accumulating energy is of grate importance. The same energy can be used to recharge the bus battery. Charging the statio'n energy wall is continuous, and bus batteries are quickly and temporarily charged. It is convinient that with the new technology the charging time is getting shorter and shorter (15 minutes), but the problem is connecting a high–power charger. Charging from the energy wall does not require a large installation power that complements the support system when contributions from renewable energy sources are small.

The accumulation of energy from hybrid systems [7] reduces the load on the electrical network and enables the use of energy near the consumer, which reduces losses in energy transmission.

Regardless of the practical use of the storage system [10], we must be aware that we have certain losses when filling and emptying the storage. It should be borne in mind that the costs of accumulation change depending on the type of accumulation Figure 14.

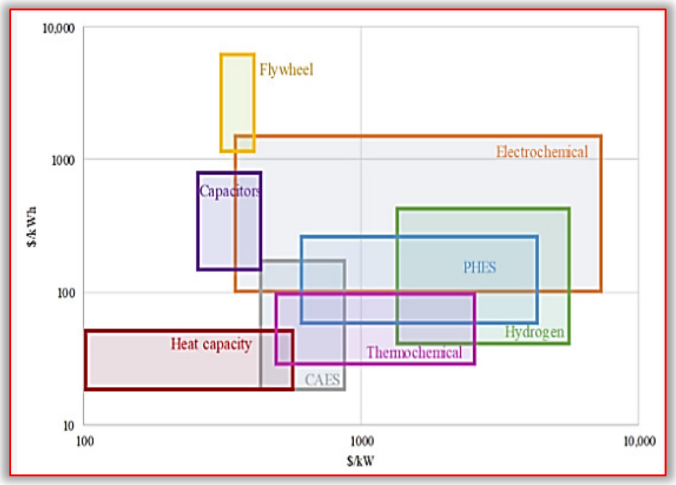


Figure 14. Cost of energy accumulation system

When accumulating energy, we must include all losses that occur during charging, during energy conservation and during discharge [14]. The attached Figure 15 shows typical places where losses occur during the accumulation and subsequent use of the accumulated energy.

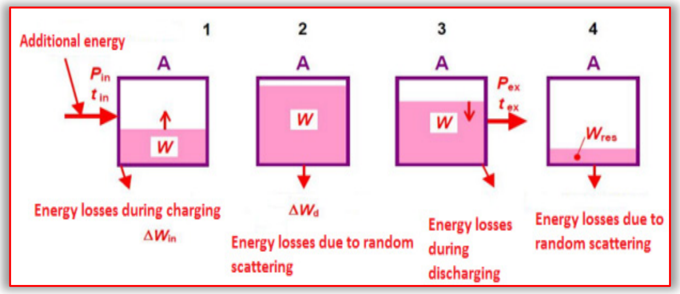


Figure 15. The state of the energy accumulator (A) (simplified)
1 – Reception of energy, 2 – Readiness state,
3 – Energy supply, 4 – Discharged state,

where Pin is the power input, Pex – output power, Tin – duration of charging, Tex – duration of energy release, 14 W is the accumulated energy Pin – power consumption, Pex – output power, Tin – duration, Wres is the residual energy, Win – loss when charging, Wex – losses in the energy release, Wd – energy loss due to random scattering The accumulation of energy is usually understood as a purposeful action.

The result is shown, for a hybrid system whose designed power does not exceed 10kW. Here the charactteristic is shown (Figure 16) for the spring, summer and early autumn periods.

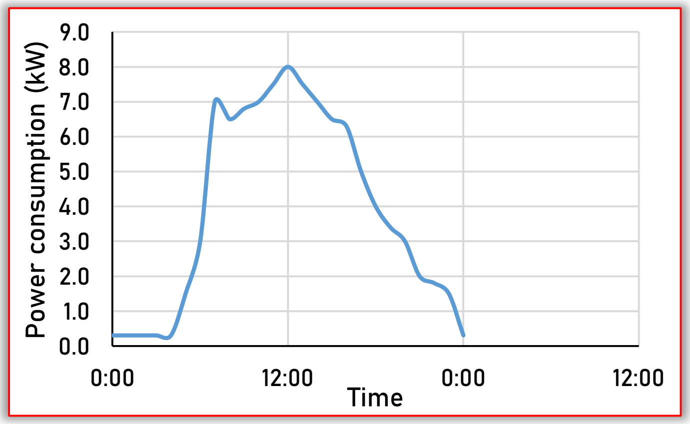


Figure 16. Daily distribution of electricity, consumption for typical activities (schedule display + charging)

The dynamics of using the battery charging system for electric buses depends on the dynamics of the traffic on the selected bus line.

CONCLUSION

The hybrid system mentioned in this paper harmonizes the operation of the solar system with the wind generator, but with complete harmony and mutual support, which gives more than double rather mutually independent systems.

An adapted bus station can be used to charge e–buses and in the option when we have a stationary system, when the station's batteries are continuously charged, and then the bus batteries are charged in a short period of time. Another option is for the selected station to supply a limited network that allows e–buses to be charged in motion. This system can be used when there is short bus stop at the final stop, the turnpike.

In case the option of using green hydrogen [20] is chosen in the future, an electrolyzer can be additionally used to convert the obtained electricity into hydrogen.

The support for the e–bus battery charging system can be provided by the infrastructure located near the station (roadside protective fence converted into an active hybrid system, sound wall for protection against traffic noise converted into a charging system, use of traffic islands with additional support).

The system can be adapted according to the choice of future drive in public transport.

References

[1] Hirahara H., Hossain M. Z., Kawahashi M., Nonomura Y., Testing basic performance of a very small wind turbine designed for multi–purposes, Renewable Energy. 30 (2005) 1279–1297.

[2] ABB Charger Catalogue, https://global.abb/group/en/technology/did–you–know/pantograph–up–for–electric–bus

[3] Ahmed A. Shaier, Ahmed A. S. Mohamed, Hamid Metwally, Sameh I. Selem – New design of high–power in–motion inductive charger for low power pulsation, Scientific report, 2023

[4] Dhote, A. Design, Analysis and Fabrication of Savonius Vertical Axis Wind Turbine, International Research Journal of Engineering and Technology, 2(3), 2015, pp. 2048–2054.

[5] Akshay, P. , Narayana K. – Low Cost Vertical Axis Wind Turbine Project, Proceedings of the 2013 Annual Conference of the American Society for Engineering Education, 2013.

[6] Vaishali A., Patil S.A., Thakur A.G. Optimization of Savonius Rotor For Wind Turbine, International Journal of Advances in Engineering & Technology, 7(4), 2014, pp. 1294–1299.

[7] Samiran N.A., Wahab A. A., Mohd S., Rosly N., Simulation study on the performance of vertical axis wind turbinE, Applied Mechanics and Materials Vols. 465–466 (2014)

[8] Rogge M., Wollny S., Sauer D. U.– Fast Charging Battery Buses for the Electrification of Urban Public Transport—A Feasibility Study Focusing on Charging Infrastructure and Energy Storage Requirements, May 2015 Energies 8(5):4587–4606

[9] Gunter M., Lenz E., Bartlomiejczyk M., Backhaus W., Korolkov S. – In motion charging innovative trolleybus, Trolleybus Committee, MAY | 2019,

[10] Grigory Kiljanov – Accumulation of energy in autonomous power plants using renewable energy sources, Energy Technology 2017 SEE–100 44 STOCKHOLM

[11] Ashkezari A., Shams L.; Jafaro H. K.; Brenna M. – Electric Bus Charging Infrastructures: Technologies, Standards, and Configurations, IEEE 2024

[12] Sarmah P., Das D., Saikia M., Kumar V., Yadav V. S., Paramasivam P., Dhanasekaran S. – Comprehensive Analysis of Solar Panel Performance and Correlations with Meteorological Parameters, ACS Omega. 2023

[13] Amjad M. , Farooq–i–Azam M. , Ni Q. , Dong M. , Ahmad Ansari E. – Wireless charging systems for electric vehicles, Renewable and Sustainable Energy Reviews, Volume 167, October 2022, 112730

[14] Roy Compton T. – Battery reference book, Reed Educational and Professional Publishing 2000

[15] Joachim G. Taiber – Overview about Wireless Charging of Electrified Vehicles – basic principles and challenges, Emobility Tec –March 2014 Edition

[16] A S J Wardhana – The Effect of Inclination Angle of The Solar Panel on The Resulting Output Voltage, Journal of Physics 2021

[17] V. Nikolić, L. Radović, B. Marković, "Symmetry of 'twins,'" Symmetry (Basel)., 7 (1) 164–181 (2015)

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