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Powering EV Charging Stations Through Hydropower

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***Abstract*—Remote communities and off-grid sites require access to reliable, renewable, and clean energy to support the growing adoption of electric vehicles (EVs). Hydropower, particularly micro- and pico-hydro systems, presents a promising solution by delivering continuous and predictable electricity to EV charging stations in locations where conventional grid infrastructure is unavailable or prohibitively expensive. This paper explores the feasibility and benefits of integrating hydropower into remote EV charging infrastructure, emphasizing its potential to reduce greenhouse gas emissions and enhance the sustainability of electric mobility. The study also discusses real-world examples, such as the Valatie Falls Hydropower Plant, and highlights the environmental and operational advantages of using hydropower over other renewable sources. By examining key challenges and opportunities, this work demonstrates how small-scale hydropower can play a critical role in expanding clean transportation options to underserved communities.**

Keywords—Hydropower, Miro-Hydro, EV charging, Remote Energy.

I. INTRODUCTION

The growth of electric vehicles increases the demand for charging stations in both urban and remote areas. While densely populated areas have benefited from the rapid expansion of the charging network, remote and off-grid sites face difficulties accessing the electrical grid [1]. Extending the electrical grid into isolated areas, such as mountainous regions, islands, rural communities, and forested territories, can be technically challenging and extremely expensive [1]. As a result, interest in distributed renewable energy sources to support EV charging has grown significantly.

Hydropower, particularly pico- and micro-scale systems, offers numerous advantages for remote sites requiring electrical power. Unlike solar and wind, which depend on environmental conditions, hydropower can operate continuously with water flow and can be implemented in any environment [2]. This continuous electricity generation aligns with the needs of EV charging, which often involves high, sustained power demand. When paired with battery energy storage systems, hydropower can deliver stable, reliable power even during peak charging events, provided it is located as close to the waterwheel as possible [2].

This paper argues that integrating hydropower—specifically at pico- and micro-scales—into EV charging infrastructure offers a focused, clean, and renewable solution to reduce pollution associated with electric vehicle energy demand [5]. By harnessing hydropower as a reliable, environmentally sustainable energy source for EV charging, it is possible to advance electric mobility while minimizing environmental impacts. The central purpose is to evaluate the extent to which hydropower can enable a cleaner transition to electrified transportation, particularly in areas with limited access to the conventional grid.

II. MATERIALS AND METHODS

Hydroelectric power could be the future of energy generation for countries. Hydropower is a renewable and one of the cleanest forms of energy. First, we begin at the micro- and pico-scale by using hydropower to power EV charging stations in remote areas, thereby expanding the reach of electric vehicles. A company has brought this concept to reality: PlugIn Stations Online (PISO) has built “one of the world’s first” hydropower EV charging stations powered by 100% clean energy, as reported in [4, par. 3] shows, “Our Valatie Falls Hydropower Plant uses a 1951 General Electric generator that produces 160 kW of continuous power. The generator now powers an ABB Wall Mount level 2 charging station. In total, the system equates to 25 miles of range per hour using 100% clean, renewable energy.” This provides proof of concept that hydropower is an effective, clean energy source capable of powering remote areas.

What makes this study so important is the significant environmental impact not only of EV production and charging, but also of all motor vehicles. If we can find a way to power our cars with renewable, clean sources, we can save and make our planet healthier. Study [6] states, “pollution from electric cars is emitted not at the places where they are used, but at the power plants where electricity is generated. In Poland, about 81% of electric energy comes from the combustion of fossil fuels (lignite, hard coal, or natural gas), and the combustion of these fuels is accompanied by the emission of carbon monoxide and dioxide, sulfur, and nitrogen oxides, but also by quite large amounts of particulate matter of various sizes (PM2.5, PM10).” We are powering our “eco-friendly” vehicles with the same power sources that all other motor directly vehicles use.

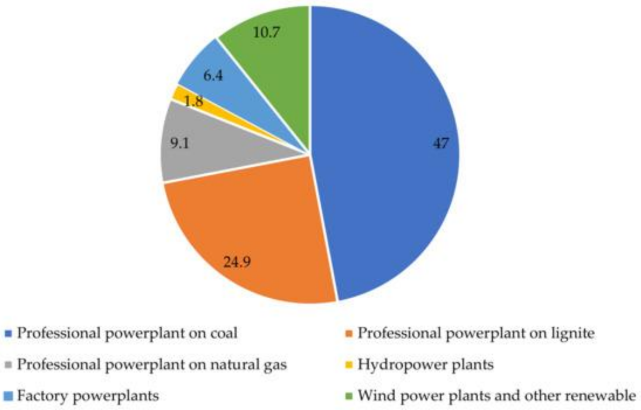

Fig. 1. Percentage share in Poland’s national electricity production of individual groups of power plants by fuel type in 2020 [6].

Most of Poland’s energy comes from fossil fuels, and only 12.5% comes from renewable, safe sources. Significant power is required not only to produce but also to charge and convert power at EV charging stations, and then to the EV itself. Energy is wasted during the conversion to EVs; the energy lost can’t be recovered, and it remains harmful to the environment. Article [7] says, “Electrical energy from the charging station is converted into chemical energy in the lithium-ion battery. The conversion process causes heat and as a result power losses.” With Hydropower, energy is still lost, but it can be replenished and is 100% clean.

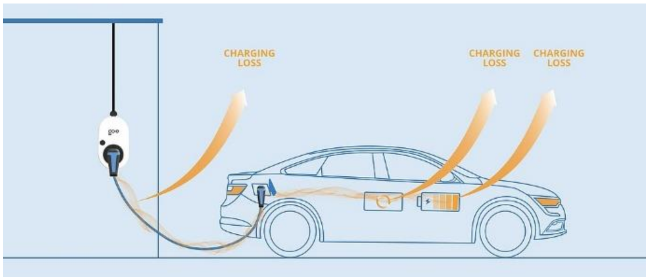

Fig. 2 Shows energy loss in the process of charging an EV [7].

The charging process of an electric vehicle is characterized by inefficiency and energy losses, mainly due to conversion processes within the battery system. These losses can be mitigated by using hydropower, which provides a consistent, reliable, and clean source of electricity.

III. DISCUSSIONS AND RESULTS

While hydropower offers a compelling solution for powering off-grid EV charging sites, it is essential to recognize the trade-offs associated with its implementation. Water is a highly effective natural energy source, and hydropower systems often require less space and deliver more consistent output than solar and wind. However, the feasibility of hydropower is constrained by site-specific factors, including the availability and reliability of water resources, local topography, and potential environmental impacts on aquatic ecosystems. Additionally, although solar and wind technologies may be less efficient in certain locations and require larger installations, they offer greater flexibility for areas with limited water resources. Thus, while hydropower's power output—determined by both the rate of flow (Q) and the head (H) can be substantial, a thorough evaluation of geographic, environmental, and technological trade-offs is essential when selecting the optimal renewable energy source for remote EV charging stations.

$$P = 9.81 * Q * H * \eta$$

η- represents the efficiency of the power plant [6].

No.	Type of Power Plant	Lifetime in Years	Area Factor in ha/MWe	Stability of Energy Production
1	Hydroelectric	100	0.01	Good
2	Photovoltaic	25	1.00	Poor
3	Wind turbine	20	20.00	Poor

Table 1. Comparison of renewable energy production methods [6].

IV. CONCLUSION

This review examined the integration of pico- and micro-scale hydropower systems into electric vehicle charging infrastructure for remote and off-grid locations. Electric vehicles are cost-effective and have lower CO2 emissions; with the addition of hydropower charging stations, EVs would be even cleaner, and the charging stations could be built in remote locations that were previously out of reach.

Challenges such as seasonal hydrological variability, regulatory complexity, and financing constraints continue to limit widespread adaptation. However, hybrid system configurations and advanced energy management systems offer practical pathways to mitigate these challenges. Overall, hydropower-based EV charging offers a technically viable and environmentally sustainable approach to expanding electric mobility in remote regions. Continued research focused on system optimization, cost reduction, and policy support will be essential to facilitate broader implementation.

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