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Feasibility Study of a Power Supply System for Large-Scale Concerts Based on Renewable Energy Electricity Supply

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Abstract. This review aims to systematically survey the current landscape of renewable energy applications in large-scale concerts, highlighting both the progress made and the persistent challenges. The technical realm this article will discuss focuses on electrical engineering, including solar power, energy conversion, piezoelectricity and energy storage. By analyzing electric power and carbon dioxide emissions during a concert, this article provides an overview of the basics of various techniques for energy conservation and emission reduction, including power distribution optimization, piezoelectricity, energy storage, and solar power. By using the Integrated Power Carbon Emission Factor Method, the mean total carbon dioxide emission is calculated. Additionally, by measuring electrical loads, this article has established a clear framework for total electrical power usage. This article also makes an example of a Coldplay concert. It utilizes techniques that contribute to energy conservation and reduce carbon dioxide emissions, demonstrating the significance of developing cutting-edge techniques and following trends in fostering green concerts. Given China's basic national conditions and technological superiority, this article compares optimized functions across various technologies to discuss the battery recycling process in electric cars and the piezoelectric effect. In conclusion, this article proposes a strategy combining piezoelectricity, solar power, and energy storage that is technically and financially feasible. Finally, future research directions and implementation pathways are suggested to realize the proposed electrical distribution model.

Keywords: Electrical engineering, piezoelectricity, solar power, electrical storage

1. Introduction

Currently, with the fast-paced development of the Chinese economy and the improvement in the quality of daily life, residential entertainment has become increasingly abundant, and the entertainment industry has undergone significant change, leading to an increasing demand for concerts. According to data from the International Energy Agency, China's annual electricity consumption in 2023 was approximately 9,220 TWh. Those from residential apartments accounted for 17.5% of total consumption, while those from the entertainment industry accounted for 8%, nearly half of those from residents. Although the proportion of entertainment is not high, reducing carbon dioxide emissions in this sector will be essential for relieving pressure on residential and industrial use.

To align with the policy of carbon peaking and carbon neutrality, many industries in China have adopted sustainable development strategies. The carbon emissions from electricity over a full year have increased from 2020 to 2035, reaching a peak of 52-67 million tons [1]. Aiming to achieve the goal of carbon peaking before 2060, carbon emissions should decline to below 10 million tons. According to data from the China Association of Performing Arts, 2,700 mast concerts that can accommodate more than 5,000 people took place in 2024. By taking the average, the total electrical consumption was approximately 0.006 TWh. Using the Integrated Power Carbon Emission Factor Method, the corresponding carbon emissions were 3500 tons. Though it was not a significant absolute value, for a public activity with considerable reputation, it has a remarkable leading role.

Among the world, Coldplay, a UK music band, has embarked on a world tour called Music of Spheres, which has made a remarkable contribution to sustainable development. This mast concert has become one of the most environmentally friendly concerts in the world. Besides, located in Helsinki, Flow Festival was one of the pioneering sustainable concerts in the world. They have measured carbon emissions from music concerts each year and have tried their best to reduce them. In 2025, the United States' Lollapalooza music festival formulated a plan to use hybrid batteries to generate electricity, combined with other sustainable initiatives, including garbage sorting and recycling. It is recommended that fans use green public transportation among other options. A growing number of prominent artists and music festivals are increasingly championing sustainability initiatives, thereby elevating public awareness and driving industry-wide changes. On the contrary, few concerts in China contribute to sustainable developments, which is a considerable gap. Fortunately, some music festivals still aim to reduce carbon emissions. For instance, Xiam music festival in Aranya launched an initiative to hold a sustainable green music festival in the coming years. However, what they really put their goal into practice is to classify garbage or clean the beach. Thus, it is imperative to strongly advertise to the Chinese public the priority of holding a green, sustainable mast concert.

To achieve carbon peaking and carbon neutrality and satisfy the public's increasing demand for entertainment, developing green and sustainable concerts is becoming a prioritised task for society to continue sustainable development. To put this plan into practice, it is crucial to analyze and improve the electric distribution system. This proposal will answer the following questions and statements: (1) What sustainable technologies have been used in mast concerts? (2) The aggregation approaches and operating strategies (3) The result of previous endeavors and the challenge that needs to be faced in the future (4) What are the specific steps in ongoing progress? This article will use realistic examples to explore various new energy resources and energy-saving technologies, conducting an in-depth research and analysis of the optimisation, restoration, and recycling of energy in concerts.

2. Research strategy

The topic of reference research primarily focuses on several keywords, such as the enhancement of piezoelectric efficiency, the application of solar panels, and the feasibility of mobile charging systems. Thanks to IEEE Explore, Google Scholar, CKNI, and Web of Science providing such state-of-the-art theses, the research process goes effectively. The approach to balancing scientific details is to determine whether a particular type of technology is suitable for its application in concerts; thus, filtering is of great importance. Also, there are still some technical issues to be considered and resolved, so the research focuses on enhancing specific details across various technologies. Since building a sustainable environment is a global challenge, technological development, such as new

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energy sources, has been advancing year by year. The range of passage selection spans mainly 2020 to 2025, including the latest technologies.

3. Theoretical basis analysis

3.1. Electric system designing principles

Big concerts usually use a stadium as a venue. Currently, mast concerts are mainly held in first-tier cities in China. In some affluent regions, there are some Class A Stadiums and Class B Stadiums. Given that big concerts are often held in prosperous cities, this article will primarily discuss the electrical systems in Class A stadiums.

The electrical system design is mainly based on JGJ 354 – 2014 Code for Electrical Design of Sports Buildings, JGJ/T 179 – 2009 Technical specification for intelligent system engineering of sports buildings, and JGJ 153 - 2016 Standard for lighting design and test of sports venues. Both the Code for Electrical Design of Sports Buildings and the Code for Electrical Design of Sports Buildings clearly require the electric distribution system of a stadium. For the primary (10 kV) power supply of this building, sports facilities classified as Grade A or higher shall be powered by dual power sources. For 220/380V electrical loads, dual power circuits shall be automatically switched at the distribution box in the terminal equipment room. The backup power supply may typically consist of a self-starting diesel generator set with a rated voltage of 230V/400V. The selection of the backup diesel generator set shall be based on its prime power rating.

3.2. Power demand for mast concerts

According to the specific standards for different power consumption of sports buildings, for super-grade sports venues, the electrical load for sports-related processes is classified as a critical load within the first-class load category; for Grade A venues, it is classified as a first-class load. In these sports-related processes, there are fire alarm systems, CCTV camera systems, or television relay systems. Attributed to the feasibility of reconstruction, using a temporary performing load to form an electric distribution system is a better approach. The table 1 below presents a systematic statistical analysis of several loads from various electrical devices [2,3] .

Table 1. Electrical loads during a concert

Catagory	Device	3 hours of Electric Energy Consumption/kwh
Mechanic System	Stage Rigging System Equipment	2.25-6
	Curtain Machine Equipment	1.5-3
	Understage Mechanic Equipment	2.25-9

Table 1. (continued)

Lighting System	Spotlight Fixtures	6.0-15.0
	Profile Lighting Fixtures	0.6-2.4
	PAR Lamps	0.15-0.6
	Floodlight Fixtures	0.36-2.28
	Followspot Fixtures	0.99-2.64
	Strobe Lighting Fixtures	0.72-1.5
	Pattern Moving Head Lights	0.6-1.8
	Wash Moving Head Lights	0.36-2.28
	Beam Moving Head Lights	0.78-1.74
	Profile Moving Head Lights	0.6-2.4
	Multimedia Digital Lights	0.3-1.5
	Overhead Batten Lights	0.15-0.6
	Ground Row Lights	0.15-0.6
Audio System	Main Loudspeakers	3-45
	Image-pulling loudspeakers	4.5-18
	Stage monitor loudspeakers	0.75-4.6
	Monitor loudspeakers	0.75-3
	Microphones	0.00015-0.0003
Others	Air conditioning system	1000-2500

Approximately, the overall electric consumption would be between 1500 kWh to 3000 kWh, which assembles a residential average family for three or five months.

3.3. Technical background

3.3.1. Photoelectric power

Photovoltaics get their name mainly based on the process of converting light to electricity. In 1839, Edmond Becquerel discovered the photovoltaic effect while conducting an experiment with an electrolytic cell, observing that the current increased when it was exposed to light. In the late 1800s, advancements were cultivated. Willoughby Smith discovered the photoconductivity of selenium; William Grylls Adams and Richard Evans Day discovered the direct conversion of photon energy into electricity. American inventor Charles Fritts was a pioneer in taking the latest discovery into practice by creating a converting device. As Albert Einstein published his insights into the photoelectric effect and numerous scientists contributed to the development of the first practical silicon solar cell, the foundations of photovoltaic power were laid. Then, over the following centuries, people dedicated themselves to improving the efficiency of converting photon energy into electricity. Apparently, photovoltaics has gained a considerable amount of maturity.

Photovoltaics mainly involves the following steps: Initially, create a solar cell made from a semiconductor with a special charged boundary, which can generate an internal electric field. When sunlight hits the core cell, by absorbing sufficient energy from photons, electrons are stimulated and jump from the valence band to the conduction band, establishing electron-hole pairs. The previously formed internal electric field then separates these electrons toward the p-type side, preventing recombination and creating a voltage difference. When a load is attached to an electrical conductor, electrons can flow through it, producing direct current.

Technically speaking, there are several drawbacks. Since photovoltaics are dependent on the climate, especially in sunny weather, they cannot be applied on a large scale. Plus, unpredictable

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weather can cause emergencies, such as desert sandstorms or destructive typhoons at the coast. Although its productivity has been enhanced in recent years, it pales in comparison to that of other new energy sources, such as nuclear power or gas power. Moreover, its zero-inertia nature makes the grid more fragile and reliant on additional technologies to remain reliable. In addition, the average annual performance degradation rate for modern crystalline silicon solar panels is approximately 0.5% per year, meaning that a typical panel will produce 87–88% of its original output after 25 years, and often more than 80% after 40 years. Therefore, it is a limitation on longevity.

Financially speaking, the generating cost varies by geological location. Also, the initial investment in it was substantial. On the contrary, because there is no need to burn fuel, its maintenance cost is low. The only cost human beings need to consider is cleaning, that is, the automatic system set on tracks.

From an environmental perspective, the production of solar panels may harm the environment. From extraction and processing, materials like Quartz, silver, copper, aluminium, and other minor metals may lead to habitat destruction, soil erosion, water contamination, and GHG emissions.

3.3.2. Charging batteries

Inside a lithium battery, it contains lithium oxide, along with magnesium, manganese, and cobalt. Using a graphite shell to store this metal oxide, lithium ions detach from the positive electrode material, migrate through the electrolyte solution to the negative electrode, and embed in the interior of the electrical appliance. These are the specific procedures for charging.

With rechargeable batteries invented by Gaston Planté, the development of the rechargeable battery has been revealed. Then, the nickel-cadmium, nickel-iron, and nickel-metal hydride batteries were gradually developed through scientific endeavour. Evolutionarily, the introduction of the lithium-ion battery symbolizes the development of portable electronics. Although there are several types of batteries as alternatives nowadays, including lead-acid, nickel-cadmium, nickel-metal hydride, lithium-ion, lithium polymer, lithium iron phosphate, and sodium-ion, the most commonly used rechargeable batteries are lithium-ion, lead-acid, NiMH, and Li-ion USB-C.

However, not only does the utilisation of batteries often come with risks due to the variety of chemicals they contain, but their production may also have a detrimental impact on the environment. Lithium, cobalt, nickel, graphite, and other metals' extractions destroy habitats, contaminate water with heavy metals, and create massive waste tailings.

Financially, due to its higher cost compared to other storage systems, it cannot replace traditional electric storage systems. Additionally, because of this, human beings cannot fully meet the goal of Renewable Energy Peak Shaving & Valley Filling, meaning batteries act as a time-shifting buffer, shifting renewable energy from periods of over-production to periods of under-production or high demand.

China leads the world, controlling most of the global Li-ion production capacity. Companies such as CATL and BYD dominate a considerable share of the global market.

3.3.3. Piezoelectricity

In 1880, French brothers Pierre Curie and Jacques Curie discovered the piezoelectric effect while studying quartz crystals, observing that an electric potential was generated when pressure was applied to certain crystals. A year later, they made a further discovery: that applying an electric field to these materials could mechanically deform a specific crystal. By the late 19th and early 20th centuries, discovery expanded on a large scale as technologies and applications advanced. For

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instance, Gabriel Lippmann and Lord Kelvin contributed to the discovery of piezoelectricity by confirming the converse effect and exploring symmetrical patterns in crystals. Until the early 20th century, piezoelectricity extended to a further level, from theory to engineering. In 1917, Paul Langevin and his collaborators developed an ultrasonic submarine detector embedded with piezoelectric quartz transducers to meet urgent needs during World War I. During the 1920s and 1930s, piezoelectric devices were widely used, including in microphones, phonograph pickups, and early radio oscillators. In the mid-20th century, the development of piezoelectricity accelerated due to the increasing demand for military radios and navigation equipment in World War II. After the war, in the 1940s and 1950s, new synthetic materials such as barium titanate and lead zirconate titanate were developed, making stronger piezoelectric responses than quartz. In the 1960s, piezoelectricity was introduced for residential use, including in lighters, watches, and ultrasound imaging. In recent decades, piezoelectric materials have been integrated into nanotechnology, and piezoelectric technology primarily powers energy-harvesting devices that convert mechanical vibrations into electricity.

The piezoelectric effect is a phenomenon where certain materials generate an electric charge in response to applied stress. There is a crystalline structure within the material, such as quartz, tourmaline, or certain ceramics like PZT, which lacks a centre of symmetry. The effect is reversible and linear with certain limits, meaning the electrical response is proportional to the applied stress. It arises from changes in polarisation within the material, which can be described mathematically using equations that involve quantities such as strain, stress, the electric field, and displacement. For instance, for the positive piezoelectric effect, where D is for electric displacement, d stands for piezoelectric strain coefficient, T represents mechanical stress, $\in^T$ stands for dielectric constant under constant stress, E is related to electric field strength,

$$D = d \times T + \in^T \times E \quad (1)$$

Piezoelectric collectors are attracting attention for their high density, ability to convert mechanical energy to electrical energy, and compatibility with various functions. Collecting human kinetic energy typically employs pressure-driven or vibration-driven methods (the latter also known as inertial-driven). These methods convert kinetic energy into electrical energy via electrostatic or electromagnetic fields or piezoelectric materials. The working principle of piezoelectric conversion technology is based on the positive piezoelectric effect, which directly converts mechanical energy into electrical energy.

The equivalent circuit of the piezoelectric effect is shown below in Fig.1

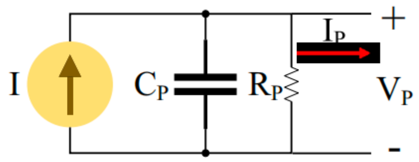

Figure 1. Piezoelectric equivalent circuit [4]

However, since choosing suitable compact materials requires substantial investment and there is limited output efficiency, their discovery and research have not yet matured. So it is crucial for human beings to have further enhancements based on this technology.

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4. Technical optimization review

To ensure the reliability of electric distribution, the lighting system and other devices in large stadium buildings can use a multi-circuit power supply. Adopted a phased implementation strategy: a temporary concert electrical system can draw power from a mobile energy storage device during a concert at First Class Sports Stadium. With sufficient control over costs and the latest technological advancements, the electrical distribution system would gradually transition to 100% energy storage, with the main power supply serving as a backup battery. If an accident happens, the system can automatically switch to supply power, fully meeting the requirements of the codes and standards [5-7].

4.1. Integration of photovoltaic installation and charging facilities

Comprehensively utilising nearby venues, such as rooftops or parking lots, is an approach to establish photovoltaic facilities and embed a DC distribution system, aiming to provide sufficient electricity to the DC lighting system. For the remaining electric energy, they will enter the AC distribution system later to enhance the feasibility of sustainable energy resources and reduce carbon dioxide emissions. In addition, during the non-concert period, to avoid wasting a large amount of photovoltaic power, the power station could provide sufficient electricity to the surrounding areas.

Arun and his teammates innovated a mobile charging system, a coin-operated mobile battery charger. Their proposal involved the use of wind turbines and solar panels to generate electrical power, and a microprocessor, the Atmega328P, that served as both an energy distribution regulator and a display of real-time energy status updates, successfully managing power flow [8]. Also, the deployment of solar panels needs to be addressed. On the one hand, installing solar panels on the stadium roof maximises solar exposure, enhancing energy conversion [9]. Plus, by installing solar panels on carports, these large-scale deployments can meet a massive amount of energy. On the other hand, Rana and her team subsequently experimented with the angle between the solar panel and the roof, aiming to maximise the total deflection of solar light. In this proposal, it is concluded that when the angle reaches 30 degrees, the deflection reaches peak value [10]. To deploy solar panels, we must determine the appropriate location for the target stadium to connect the electronic devices and the solar power conversion system. Additionally, when an emergency occurs, establishing modern deployment for solar panels is essential.

4.2. Using mobile energy storage system as electric distribution station

Preventing air and noise pollution from mobile diesel generators by using a mobile energy storage system as an electricity-distributing battery can help realise the dream of temporary electric distribution without pollution. Plus, to get used to fluctuations in the electric distribution system from photovoltaic power, storing surplus photovoltaic power during the day for nighttime lighting can improve the feasibility of sustainable energy holistically.

Kuo and his teammates applied a mobile energy storage system in a microgrid management system. They embedded a flexible energy storage system with an edge server, a power supply socket to support various voltage levels, and a stationary energy storage system, which enhances the energy system's flexibility [11].

Here are some calculations for analysing the feasibility of the scheme. Assume the total load power for a single concert is 1000 kW, and each storage car can deliver 400 kW of electricity. Based on the power calculation, with at least three storage cars, can the electric power meet the usage

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demand? A limitation of three storage cars results in a total energy capacity of 2400 kWh, which is inadequate to fulfil the 3000-kWh individual requirement. Using four storage cars with an average discharge power of 250 kW, the total power will be 1600 kW, and the total energy will be 3200 kWh. Thus, they can continue discharging for 3.2 hours, which appropriately satisfies distributing electric power for a concert, forming a constructive scheme.

Realistically, Johan Cruijff Arena in the Netherlands has contributed significantly by implementing this approach. According to current research, there are over 148 Nissan Leaf batteries and 4200 solar power boards inside the stadium, arranged in the energy distribution system at Eaton. Therefore, it has formed the biggest energy storage system around Europe. Thanks to this system's sufficient capacity, it not only reduced diesel generator utilisation but also alleviated peak electricity demand, supporting residential use and reducing pressure on the local power grid.

4.3. Piezoelectric technology

Despite using clean energy to generate electricity, recycling and collecting energy generated by humans are among the most viable methods as well. Given the scale of mast concerts, using an individual's kinetic energy to generate electricity is a great way to promote sustainable development. There is potential to use piezoelectric technology as well, since it can continuously generate kinetic energy.

However, the conversion from kinetic energy to electrical energy is so small that it decreases the overall efficiency. Several researchers have conducted in-depth research on how to maximise energy conversion in piezoelectric technology. Yin and her team proposed a low-frequency isostress stair piezoelectric harvesting device, suggesting that an external circuit is necessary to improve output efficiency by embedding a resistance equal to the equivalent value [12]. Huang and her teammates designed a magnetostrictive vibration energy harvester and concluded that it can maintain a constant voltage and simplify impedance matching, thereby achieving a positive efficiency [13]. Brahim and his teammates argued that high-quality materials with high electromagnetic coefficients and low electrical and mechanical losses are more likely to achieve high conversion efficiency. The proposal primarily focused on improving the conversion of mechanical energy to electricity, underscoring the importance of energy conversion in the field study of piezoelectricity [14].

5. Case study: music of spheres

In 2020, Coldplay committed to using a greener, more recycled approach to hold a worldwide concert. Then, they began cooperating with the relevant department, making plans and discussing competitive green strategies.

In April 2025, at the concert in Hong Kong, multiple stadium floors are designed as "Kinetic Floors", which are piezoelectric, and they were aggregated in the Energy Centre. A kinetic-energy-transferring floors consist of 44 sustainable kinetic dancefloor tiles. With the contribution of the powerful dancefloors, they are capable of generating more than 640 watts of sustainable output. The device comprises components such as a piezoelectric power generation structure, an energy storage module, a rectification module, and a charging chip [15]. When the device is subjected to human foot pressure, the instantaneous alternating current is rectified and filtered by the rectification module. When fans are dancing on the kinetic floor, the kinetic energy generated by stepping would convert to electrical energy, reducing demand on the electrical distribution system.

Additionally, through a collaboration with BMW, Coldplay used up to 40 recycled BMW i3 batteries to retain power. According to some statistics, every recyclable BMW i3 battery has an 80%

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DoD, a capacity of 42 kWh, and an energy density of 152 Wh/kg [16]. To charge the battery from 10% SoC to 80%, DC charging is particularly important, as it can be completed in half an hour, whereas AC charging takes 11 hours. By summing all the data, the total capacitance can reach 1680 kWh. With the help of other technologies, such as the piezoelectric effect and triboelectricity, the total would be 2000 kWh.

Since Coldplay announced their worldwide tour, Music of Spheres, in 2021, they have promised to reduce carbon dioxide emissions by 50%. Until June 2024, due to their official website, they have reduced carbon dioxide emissions by 59% compared to 2016 and 2017 [17].

6. Challenges and ongoing process

Based on previous analyses and analogies, there are numerous challenges that human beings need to overcome.

The low productivity of piezoelectricity: Due to energy losses and the limited kinetic energy available from human beings, overall efficiency is relatively low. Because of the different materials, such as polyelectrolyte polyvinylidene fluoride acetate, it only transfers 1.1 mW. Plus, the conversion process of energy involves significant energy loss, since kinetic energy needs to be transferred into electrical energy in the piezoelectric board, then into an electrical current for electronic devices. However, this passage discusses how to improve output efficiency by changing materials or optimising the conversion system.

High risk of batteries: Although lithium-ion batteries have high storage efficiency and a high depth of discharge, their internal chemicals pose a risk of explosion. If the circuit is overcharged, the voltage exceeds the upper limit, causing a lithium-ion cell overload. The thickened solid electrolyte interphase (SEI) film on the negative electrode surface ruptures due to excessively high pressure and temperature, triggering electrolytic decomposition and oxidation of the harmful electrode material. If the circuit is over-discharged, excessive depletion of the negative electrode causes the thickened SEI film to decompose, followed by dissolution of the copper foil current collector. This results in the formation of copper dendrites that penetrate the separator and induce an internal short circuit. If a short circuit occurs due to increased heat, oxidation between positive and negative charges becomes stronger, releasing more energy and leading to an explosion. However, human beings cannot eliminate this risk but mitigate it by applying immediate safeguards, such as rigorous manufacturing controls or triple BMS hardware-software protection.

7. Conclusion

Fueled by the goals of carbon neutrality and carbon peaking, this article primarily discusses the electricity demand of selected concerts. It provides an overview of technologies that can be used to support a green concert, including photovoltaics, battery charging, and piezoelectricity. Then, given the unique characteristics of Chinese development, this article proposes three main enhancements to advance China's green energy initiatives, including integrating photovoltaic installations and charging facilities, using mobile energy storage systems, and adding piezoelectricity.

This article seeks to raise awareness of this issue, inspire public action, and make a meaningful contribution. With ongoing developments, converting this scheme into reality could make a significant contribution to reducing carbon dioxide emissions. However, several obstacles still need to be overcome, such as enhancing piezoelectricity's efficiency, reducing power loss, and developing a technical and practical scheme for a specific stadium.

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