Unplugging the Grid: Energy Surety via Wireless Power

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INTRODUCTION

Since the advent of the industrial age, technological breakthroughs have defined civilization's advancement. Whether describing the evolution of transportation, mass production, communications, medicine, information technology, or weaponry, it is impossible to overstate the incredible impacts of new technologies. One technology, hearkening from the industrial era—electrical power and its generation, transmission, and distribution systems—is an enabler for virtually every other area of scientific and technological achievement. Access to electrical energy is the lifeblood of technology, powering scientific and engineering progress across many disciplines and enabling gains in living standards. Without continued access to secure, reliable, and affordable electrical power, the world would become dark, in every sense of the word.

The wired power grids that link us to electricity are outdated, vulnerable to attack from natural and man-made threats, and limited in their abilities. Microgrids, smart grids, and dynamic distribution systems are helping make our grids more resilient, but these technologies are expensive and limited. What if there was a means of directly transferring electricity to local distribution systems without relying on either internal generation or an externally wired grid?

This article introduces the use of an electromagnetic phenomenon called the Zenneck surface wave to wirelessly transfer power from a secure external power generation source directly to a local distribution network without using traditional macrogrid architecture. It discusses the fragility and limitations of the current electrical grid, describes the unique physical characteristics and historical evolution of Zenneck surface wave technology, and tracks its development. The article concludes with a discussion of the implications of this groundbreaking technology.

TODAY'S FRAGILE GRID

Despite our taken-for-granted dependence on electrical power, its conveyance method—the transmission grid—is aged and fragile. This raises concerns of increased risk of catastrophic failures which could lead to long periods of widespread power outages. With greater dependence on the electric grid, its vulnerabilities have increased and its reliability has declined. Most of the five million miles of electrical lines in the U.S., including 200,000 miles of high-voltage transmission lines, were built in the 1960s and 1970s utilizing components that Thomas Edison would recognize [1]. Blackouts occur four times as often as they did just fifteen years ago, largely due to increasing age and excessive demands on the system [2]. Weather events that once caused about 20% of system outages now account for about 70%, including catastrophic outages from hurricanes and tsunamis [3].

Our aging electric grid is increasingly threatened from physical, cyber, and electromagnetic pulse (EMP) attacks. The U.S. grid experienced 274 physical attacks over the last three-year period ending in 2015. This included the 2013 Metcalfe Substation attack when a single gunman disabled 17 transformers in only 19 minutes [4]. Cyber attacks against supervisory control and data acquisition (SCADA) systems occur approximately once every four minutes [5]. A large-scale attack could lead to outages lasting many months [6]. The biggest threat to our terrestrial grid may come from outer space. Scientists estimate that a natural solar disturbance or a man-made electromagnetic pulse attack from a nuclear weapon detonated at an altitude of 300 miles could disable the entire U.S. electrical power system [7].

Absent these threats, today's power grid has serious limitations. While conventional high voltage electrical transmission lines are 90% efficient over short distances, they are expensive to construct ($1 to $3 million per mile), and must overcome numerous environmental regulatory hurdles [8]. Because of these issues, electrical power plants must be located near centers of demand, restricting the viability of renewable generation sources including solar, wind, geothermal, and hydro-electric, which slows the pace of electrical power deployment in developing countries where 1.2 billion people lack access to electricity [9].

ENHANCING THE GRID

Many new technologies and engineering techniques have been offered to upgrade and better safeguard our grids. These include microgrids, which are self-contained groupings of electricity generation sources, distribution infrastructure, and loads, able to function autonomously from a centralized macro grid structure. Smart grids are those with two-way interactive capacity that enable automatic rerouting when equipment fails or outages occur. Electric companies are employing dynamic distribution systems to seamlessly and reliably integrate intermittent renewable generation sources like solar and wind into the current grid architecture. But these approaches are expensive and limited in the degree of resilience they can provide to our mammoth grid architecture.

What if there were a means of transferring electrical power directly from a generation source to a local distribution network without using internal generators, external grids, or sophisticated electronic protection systems? There is one emerging technology that offers an alternative solution with strategic implications.

THE ZENNECK SURFACE WAVE

Texzon Technologies is developing a technology that employs an electromagnetic phenomenon, the Zenneck surface wave, to wirelessly transfer megawatts of power efficiently. A Zenneck surface wave is an electromagnetic wave that uses the surface of the Earth as a waveguide enabling it to carry communications signals or electrical power efficiently over long distances. This breakthrough technology called Texzon Wireless Power™ (TWP), will enable local power distribution networks to be externally powered from a multitude of dispersed, secure, redundant generators, obviating the need for organic power generation internal to a grid, greatly reducing many of the vulnerabilities and limitations of conventional grid designs.[1]

TWP employs a transmitter probe located near a power generation plant to launch a Zenneck carrier wave. Receiver systems appropriately positioned around the world will receive the signal and download the power into a local microgrid or conventional grid architecture. This wireless power system will enable any existing power plant or generation source to deliver power directly to a terminal grid anywhere on

Earth, replacing the long-distance, high-voltage wired segment of the current system.

Physical Characteristics

The Zenneck surface wave possess several physical characteristics that make it very attractive for global electrical power transmission. The wave is impervious to weather effects such as lightning, geomagnetic disturbances, or electromagnetic pulses (EMP), including those associated with a nuclear detonation. Unlike a wired grid, the wireless portion of a Zenneck wave system cannot be physically attacked. It is also very challenging for cyber attacks to target or cause cascading failures to a wireless system. Furthermore, at optimum transmission frequencies, the Zenneck wave is unaffected by variances in terrain or large man-made objects such as skyscrapers. It effectively "sees" the earth as a smooth, extremely efficient electrical conductor enabling it to wirelessly transfer electricity with greater efficiency than conventional transmission systems. When launched, the Zenneck surface wave literally envelops the planet like a balloon, enabling transmitter probes to be placed anywhere power can be generated and receivers to be placed anywhere power is needed. Once the Zenneck wave is launched and the wireless system is connected, electrical power flows directly from connected generators to any receiver experiencing a demand from a load.

One might naturally ask whether such a groundbreaking system raises safety concerns or could cause harmful effects to the environment. Notably, even today's conventional high voltage power lines produce harmful levels of radiation requiring standoff distances for homes or businesses. The American National Standard Institute (ANSI) acceptable limit for radio frequency (RF) fields is 614 V/m for all electromagnetic field intensities.[2] Fortunately, wireless power carried by Zenneck surface waves is calculated to generate RF radiation levels less than 10% of the current ANSI safety standard. Thorough testing will be required to ensure that measured radiation levels match these theoretical predictions.

Another potential concern involves the threat of piracy, or unauthorized interception of the wireless power signal. Although this is theoretically possible it would require detailed knowledge of the appropriate frequency and receiver configuration. Additionally, TWP has several available techniques, developed in the communications industry to encrypt or otherwise protect the signal.

Fast Track to Commercialization

Given the revolutionary nature of wireless power one might imagine this technology is many years away from realization. Remarkably, TWP is on a fast track to commercialization. Over 200 domestic and international patents have been filed to secure the intellectual property which describes the equipment and the techniques necessary to create a global system. Dozens of experiments and demonstrations have been conducted at multiple locations, documenting the ability to wirelessly transfer power across a range of frequencies and distances. In every instance, experimental data has matched theoretical predictions for Zenneck wave field strengths and ranges. In 2016, the inventors of this technology presented their analysis, experimental data, and conclusions at an Institute of Electrical and Electronics Engineers (IEEE) conference at Baylor University [10]. Subsequent presentations have been provided to numerous commercial entities, U.S. governmental organizations and conferences [11,12]. The Federal Communications Commission (FCC) and National Telecommunications and Information Administration (NTIA) are engaged to coordinate frequency allocation requirements. Construction is underway on a full-scale transmitter probe to demonstrate the ability to transfer megawatts of utility grade electricity to receivers placed around the globe.

HISTORICAL EVOLUTION

Readers might wonder how such a disruptive technology like wireless power could have remained undiscovered until now? The answer lies in the historical evolution of electromagnetic wave theory originating with the work of physicist James Maxwell and his famous equations of 1864. The German physicist, Heinrich Hertz, generated a continuum of solutions to Maxwell's equations to derive and experimentally prove (1886-88) the existence of Hertzian radiated waves [13]. These ground waves as they are commonly termed are employed by a multitude of radio (AM, FM, SW, microwave, cell phone, etc.) communication devices that we use today. From 1907-1909 two other German physicists, Jonathan Zenneck and Arnold Sommerfeld, theorized the existence of an alternative form of electromagnetic wave, a surface wave, and derived its mathematical expression as an exact solution to Maxwell's Equations. Zenneck and Sommerfeld mathematically proved their surface wave theory but never experimentally measured or demonstrated it.

In the early years of the twentieth century, two theories of electromagnetic wave theory co-existed: classic Hertzian radiated waves (ground waves), transmitted via conventional antennae on a line of sight path and dissipated over a distance into space; and Zenneck surface waves, which use the surface of the Earth as a waveguide and travel at high levels of efficiency but had not been experimentally observed. Guglielmo Marconi was aware of these competing wave theories while conducting his own experiments in radio communication and speculated that perhaps some combination of Hertzian radiation and Zenneck surface waves might be behind the successful propagation of the wireless telegraph signals he sent across the Atlantic [14].

Seneca Lake Experiments and the Infamous Sign Error

In the 1930s as radio communication became pervasive, pressure increased to solve the mystery between Hertzian ground radiation and Zenneck surface waves to regulate the frequency spectrum and transmission power levels and prevent cross-interference from radio transmitters. Two scientists, C.R. Burrows of Bell Laboratories and Kenneth Norton of the newly-formed FCC, devised and conducted experiments at Seneca Lake, New York in 1936 to measure and document the existence of the respective wave phenomena. But during their experiments, Burrows and Norton were unable to generate or detect the Zenneck surface wave using a conventional dipole antenna. Their collected data reflected only conventional Hertzian radiated ground waves [10].

In striving to explain their results, Norton studied Zenneck's surface wave equations and reported a sign error, which if corrected, eliminated the theoretical existence of the electromagnetic Zenneck surface wave [15]. This finding closed the book on surface wave theory leading subsequent generations of electrical engineers to be taught that Zenneck surface wave theory had been debunked [10]. Subsequently, FCC regulations and guidelines were based solely on Hertzian ground wave theory.

Decades later, two scientists became interested in Zenneck surface wave theory and re-evaluated its mathematical foundations. One of these, Dr. James Corum, determined that Zenneck and Sommerfeld's original mathematical proofs and solutions to Maxwell's equations were correct. Zenneck's mathematical expression of the surface wave was subsequently validated by two other researchers, one at Case Western University and one from Texas A&M University [16,17]. After years of tedious research, Dr. Corum and his team eventually devised and patented a method to successfully launch a Zenneck surface wave that matched theoretical predictions. In 2014, Dr. Corum and his bother Ken Corum, duplicated Burrows' and Norton's Seneca Lake experiments, launching the Zenneck surface wave, and detecting field strengths several orders of magnitude greater than predicted by conventional Hertzian ground radiation [10]. Zenneck surface wave theory was reconsidered, along with the potential for the realization of wireless power transfer on a global scale.

IMPLICATIONS

While it is nearly impossible to list all the implications of such a revolutionary technological breakthrough, many important ramifications are apparent.

Increased Energy Surety

By eliminating much of the fragility and vulnerability of the current system, TWP will result in a more resilient electrical power architecture and improve energy surety for critical infrastructure and defense applications. With TWP, microgrids and conventional grids can be externally powered from redundant locations. Protection from physical/cyber attack and EMP can be focused on the terminal points of the system—power plants, transmitter probes, receivers, substations, and local destination grids. Damaged or offline generators can be instantaneously and virtually replaced by switching to backup generators elsewhere on the globe.

Accelerated Recovery Times

Wireless power systems will enable accelerated recovery from natural disasters or physical catastrophes. Transportable receiver units can be delivered to reactivate damaged grids, allowing power from generation sources outside disaster zones to flow directly to areas affected by weather events or conflicts. Lead times necessary to rebuild power plants in the aftermath of a disaster will be eliminated since substitute generators with excess capacity will be wirelessly tapped from anywhere on the globe. No longer will disasters inflicted by nature or conflict necessarily result in months or years of pervasive power outages.

Power to the Developing World

Another far-reaching implication of wireless power is the potential to rapidly expand affordable electrical power to the developing world decades ahead of projected timelines. In 2013, 17% (1.2 billion) of the world's population lacked access to reliable electricity [9]. Clean, safe, reliable, and affordable wireless power systems will remedy this, enabling necessities like hot meals, advanced medical treatment, and clean drinking water for people in the developing world. No longer will a lack local of energy resources, financial resources, or generating capability limit the local availability of electrical power.

Streamlined Energy Supply Chains

Global wireless power will also lean world energy supply chains. Why waste resources transporting coal, oil, or natural gas to distant generation facilities when future generation plants can be built at the site of the fuel source, with the capability to directly transfer energy anywhere on the planet? Similarly, fuel trapped at remote locations and therefore too costly to transport, can be mined and converted to electricity at the source. Global energy will shift from moving molecules to moving electrons around the planet.

Optimizing Renewables

Wireless power will raise the viability of renewable energy, bringing untapped or stranded resources onto global markets. No longer will renewable energy generation facilities need to be located near population centers, but instead will be sited at optimized locations from an energy gathering standpoint, enabling cost-effective delivery of green energy anywhere. The efficient global transportability of wireless power will incentivize the construction of huge solar arrays in remote deserts, wind farms in windy areas, vast geothermal plants in Iceland, and hydroelectric facilities near moving water without penalty for distance from populated areas or intermittencies due to day/night variances in local power demand. The resultant enhanced economic attractiveness of renewable energy resources will lead to a radical increase in the proportion of clean energy utilization across the planet.

CONCLUSION

The transition of electrical power transmission systems from today's aging, fragile wired grids to a global wireless system utilizing the Zenneck surface wave will be one of the most important technological developments of the twenty first century. This breakthrough will effectively "cut the cord" between optimally-sited power generation facilities and local distribution grids, enhancing the energy surety, efficiency, and resiliency of the world's electrical transmission system. Wireless power will be a global economic catalyst, accelerating the delivery of clean, affordable power to parts of the planet where reliable energy does not exist, improving the standard of living for millions. In the words of one scientist, "Texzon Wireless Power will do for energy what the internet has done for information" [18].

End Notes

1. Texzon Wireless PowerTM (TWP) is a trademark of Texzon Technologies and is used in this article to describe a proprietary technological system employing Zenneck surface waves to wirelessly transfer electrical power.
2. Institute of Electrical and Electronics Engineers (IEEE) C95.1–2005: The complete name is Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, IEEE C95.3–1999 is the measurement practices standard.

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