THE MICROGRID UNPLUGGED: ENERGY SURETY VIA WIRELESS POWER

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ABSTRACT

Microgrids have been touted as an important enhancement to global energy surety. Traditionally, a microgrid has been defined as a localized grouping of electricity sources, distribution infrastructure, and loads, able to function autonomously from the centralized macro grid structure. Due to the inherent risks associated with external macro grids, the assumption has always been that the microgrid's energy source must be organic—within the microgrid architecture. But what if there was a way to directly transfer power to the microgrid without reliance on either an internal generator or an external grid? This paper introduces the use of an electromagnetic phenomenon called the Zenneck surface wave to wirelessly transfer power from a secured external power generation source directly to a microgrid without reliance on traditional wired macrogrid architecture. It discusses the fragility and limitations of the current grid, describes the unique physical characteristics and historical evolution of Zenneck surface wave technology, and tracks its developmental status. The paper concludes with a discussion of the implications of this groundbreaking technology.

INTRODUCTION

Ever since the advent of the industrial age, continual technological breakthroughs have shaped civilization's advancement. When describing the evolution of transportation, mass production, communications, medicine, information technology, or even weaponry, it is impossible to overstate the incredible impact that emerging technologies have had upon our world. One technology hearkening from the industrial era—electrical power and its distribution systems—is an enabler for virtually every other area of scientific and technological achievement. In fact, electrical power is the lifeblood of technology, enabling standard of living gains and powering technological and scientific progress across many disciplines. Without continued access to secure, reliable, and affordable electrical power, our planet would go dark, in every sense of the word.

TODAY'S FRAGILE GRID

Despite our taken-for-granted dependence on electrical power, the transmission grid is showing its age and fragility, raising concerns of increased risk of catastrophic failures which could lead to long periods of widespread power outages. Ironically, as we've increased our dependence on the grid, its vulnerabilities have increased while its reliability has decreased at an alarming rate. 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[1] utilizing components that Thomas Edison would recognize. Blackouts occur at four times the rate of fifteen years ago due to increasing age and excessive demands on the system.[2] Weather events that used to cause about 20% of system outages now account for around 70%,[3] including catastrophic outages from hurricanes and tsunamis.

Besides getting old, our grid is also under increased threat from physical, cyber, and electromagnetic pulse (EMP) attack. The U.S. grid experienced 274 physical attacks over the last three years including the 2013 Metcalfe Substation attack when a single gunman took out 17 transformers in 19 minutes.[4] Cyberattacks 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 as described in Ted Koppel's recent book, *Lights Out*.[6] But 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 electrical power system of the U.S.[7]

Even absent these threats, today's power grid has serious limitations. Although conventional high voltage transmission lines are 90% efficient over relatively short distances they are enormously expensive to construct ($1-3 million/mile), requiring a litany of environmental assessments and regulatory hurdles.[8] Because of this, power plants must be located as close as possible to centers of demand, restricting the viability of renewable generation sources like solar, wind, geothermal, and hydro-electric, and slowing the pace of deploying electrical power to the developing world where 1.2 billion people still lack access to electricity.[9]

POWERING MICROGRIDS

Microgrids—localized groupings of electricity generation sources, distribution infrastructure, and loads, able to function autonomously from the centralized macro grid structure—have been offered as one way to mitigate the vulnerabilities of today's conventional power grids and enhance energy surety. Due to the inherent risks associated with external macro grids, the assumption has always been that a microgrid's energy source must be organic—within the grid architecture. But what if there was a way to directly transfer power to the microgrid without reliance on either an internal generator or external grid? This paper will discuss 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 microgrid without reliance on traditional wired macrogrid architecture.

WIRELESS POWER UTILIZING THE ZENNECK SURFACE WAVE

Texzon Technologies is developing a technology employing the use of a little known physical phenomenon, the Zenneck surface wave, which has the ability to wirelessly transfer megawatts of power from any point on earth to any point on earth with very high efficiency. 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)[10], will enable microgrids, or macrogrids for that matter, 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 architectures.

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. It is important to note that this wireless power system will be able to employ any existing power plant or generation source to deliver power directly into any 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 or geomagnetic disturbance 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 cyberattacks to target or cause cascading failures to a wireless system. Furthermore, at proper transmission frequencies, the Zenneck wave is unaffected by variances in terrain or large man-made objects such as skyscrapers. In effect, it "sees" the earth as a smooth, extremely efficient electrical conductor allowing it to wirelessly transfer electricity with greater efficiency than conventional transmission line 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 RF fields is 614 V/m for all electromagnetic field frequencies in the range that would be useful for Zenneck surface waves.[11] 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.

Fast Track to Commercialization

Given the revolutionary nature of wireless power one might imagine this technology is many years away from realization. Not so. Remarkably, TWP is on a fast track to commercialization. Nearly 100 domestic and international patents have been filed securing the intellectual property describing the equipment and techniques necessary to stand up 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 case, experimental data has matched theoretical predictions for Zenneck wave field strengths and ranges. On March 31, 2016, the inventors of this technology presented their analysis, experimental data, and conclusions at an IEEE-sponsored conference at Baylor University.[12] Subsequent presentations have been provided to numerous commercial entities and U.S. government organizations including a Society of American Military Engineers Conference in Phoenix on May 24, 2016.[13] The Federal Communications Commission (FCC) and National Telecommunications and Information Administration (NTIA) are engaged to coordinate frequency allocation requirements. Design work is essentially complete and construction has begun on a full-scale "transmitter probe" that will be the centerpiece of the Global Demonstration Project that will demonstrate the ability to send megawatts of utility grade power to receivers placed around the globe.

HISTORICAL EVOLUTION

Anyone reading this paper 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 Clerk Maxwell and his famous "equations" of 1864. The later 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.[14] These "radio 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 demonstrated or measured it.

So in the early years of the twentieth century, two theories of electromagnetic wave theory co-existed: classic Hertzian 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.[15]

1936 Seneca Lake Experiments and the Infamous Sign Error

In the 1930s as radio communication became pervasive, pressure increased to solve the mystery between Hertzian waves and Zenneck surface waves in order to properly regulate the frequency spectrum and transmission power levels in order to 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, NY 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 antennae. So their data reflected only conventional Hertzian waves.[16]

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.[17] His "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.[18] As a result, subsequent FCC regulations and guidelines were based totally on Hertzian wave theory.

Decades later, two scientists took an interest in Zenneck surface wave theory and re-evaluated its mathematical foundations. One of these, Dr. James Corum, found that Zenneck and Sommerfeld's original mathematical proofs and exact solution to Maxwell's equations were not flawed but entirely correct. In fact, 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.[19] 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, revisited Burrows' and Norton's Seneca Lake experiments, and this time were able to launch and measure the Zenneck surface wave, detecting field strengths several orders of magnitude greater than predicted by conventional Hertzian wave radiation.[20] Zenneck surface wave theory was back, along with the potential for the realization of wireless power transfer on a global scale.

IMPLICATIONS

While it's nearly impossible to list all the implications of such a revolutionary technological breakthrough, many significant ramifications are quite apparent.

Increased Energy Surety

First, 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/cyberattack 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 will be flown in to reactivate damaged grids, allowing power from generation sources outside the disaster zone to flow directly to an area affected by a weather event or conflict. 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 mean 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.[21] 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 right 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 today, can be mined and converted to electricity right at the source. In short, global energy will shift from moving molecules to moving electrons around the planet.

Optimizing Renewables

Finally, wireless power will significantly raise the viability of renewable energy, bringing untapped or "stranded" resources onto global markets. No longer will renewable energy generation facilities (solar, wind, hydro, geothermal) 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 anywhere moving water can be tapped with no 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 generation across the planet.

CONCLUSION

In the final analysis, 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 significant technological developments of the twenty first century. This breakthrough will effectively "cut the cord" between optimally-sited power generation facilities and local distribution grids and microgrids, 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."[22]

ABOUT THE AUTHOR

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REFERENCES

[1] Jennifer Weeks, “U.S. Electrical Grid Undergoes Massive Transition to Connect to Renewables,” *Scientific American*, April 28, 2010, http://www.scientificamerican.com/article/what-is-the-smart-grid/

[2] Jordan Wifrs-Brock, “Power Outages On The Rise Across The U.S.”, *Inside Energy*, August 18, 2014, http://insideenergy.org/2014/08/18/power-outages-on-the-rise-across-the-u-s/

[3] Kristen Rodman, Severe Weather Poses Threat to Archaic US Power Grid,” *AccuWeather*, September 11, 2013, http://www.accuweather.com/en/weather-news/severe-weather-us-power-grid/17498060

[4] Center for Security Policy, *Physical Attack*, 2015, http://securethegrid.com/wp-content/uploads/2016/06/Grid-Vulnerability-Brief1.pdf

[5] Center for Security Policy, *Cyber Attack, 2015,* http://securethegrid.com/wp-content/uploads/2016/06/Grid-Vulnerability-Brief1.pdf

[6] Ted Koppel, *Lights Out: A Cyberattack, A Nation Unprepared, Surviving the Aftermath* (New York: Crown Publishers, 2015)

[7] *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack*, April 2008, http://www.empcommission.org/docs/A2473-EMP_Commission-7MB.pdf

[8] Matthew H. Brown and Richard P. Sedano, *Electricity Transmission: A Primer*, National Council on Electricity Policy, June, 2004

[9] *Energy Poverty*, International Energy Agency, http://www.iea.org/topics/energypoverty/

[10] Texzon Wireless Power™ (TWP) is a trademark of Texzon Technologies and is used in this paper to describe a proprietary technological system employing Zenneck surface waves to wirelessly transfer electrical power.

[11] 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.

[12] K.L. Corum, Brig Gen M.W. Miller, Ph.D., and J.F. Corum, Ph.D., *Surface Waves and the Crucial Propagation Experiment*, Texas Symposium on Wireless & Microwave Circuits & Systems, IEEE Microwave Theory and Techniques Society, Baylor University, Waco, Texas
March 31-April 1, 2016.

[13] Richard T. Devereaux, “Texzon Wireless Power: Cutting the Cord on a Global Scale,” Panel on Disruptive Emerging Technology in Energy, Joint Engineer Training Conference and Expo, Society of American Military Engineers, Phoenix, AZ, May 24, 2016.

[14] Hertz, H., *Electric Waves*, translated by D.E. Jones, Macmillan, 1893; Dover reprint, 1962.

[15] Ratcliffe, J.A., “Marconi: Reactions to His Transatlantic Radio Experiment,” *Electronics and Power*, May 2, 1974.

[16] Corum, Miller, and Corum, p. 5

[17] Norton, K.A., “The Propagation of Radio Waves over the Surface of the Earth and in the Upper Atmosphere – Part I,” *Proceedings of the IRE*, vol. 24, 1936, pp. 1367-1387.

[18] Corum, Miller, and Corum, p. 7

[19] Collin, R.E., "Hertzian Dipole Radiating Over a Lossy Earth or Sea: Some Early and Late 20th Century Controversies," *IEEE Antennas and Propagation Magazine*, vol. 46, No. 2, April 2004, pp. 64-79.

[20] Corum, Miller, and Corum, p. 6

[21] *Energy Poverty*, International Energy Agency, http://www.iea.org/topics/energypoverty/

[22] Dr. Randall Jean, Ph.D., Remarks at Texas Symposium on Wireless & Microwave Circuits & Systems, Baylor University, Waco, TX, March 31, 2016.