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U.S. Electrical System Reliability: Deregulated Retail Choice States' Evidence and Market Modeling

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ABSTRACT: The goal of this paper is to test if the promised U.S. electrical system high reliability standards are being maintained, once states deregulate their electric utilities. This research is the first in the literature to combine states that offer retail choice, by deregulating their electric utilities, with North American Electric Reliability Corporation reserve margin forecasts, from 2014-2023, to analyze whether deregulated retail-choice states are adding adequate generating capacity to meet demand, and thus provide high electrical system reliability, when compared to the U.S. as a whole. This paper's results on electrical system reliability in the deregulated states are timely and important for U.S. electricity energy policy. Additionally, this is the first paper in the literature to propose a new space-time business model that adequately addresses the complex, multidiscipline, multidimensional, U.S. electrical system deregulated market. Future research will specify the new business model's mathematical formulation.

Keywords: U.S. electrical system reliability; Electric utility deregulation; Electricity "energy only" and "capacity markets."
JEL Classifications: G31; G38; H44; K23

1. Introduction

Electrical system reliability in developing countries is substandard, because electrical system capital expenditures are inadequate and generating and transmission infrastructures are incompetently managed. One alternative to having sufficient generating capacity is rotational load shedding, used to contain a cascading system blackout, which may occur during conditions of either significant over demand or under supply. Frequent rotational load shedding occurs—up to 20 hours each day—in most developing countries. However, rotational load shedding in developed countries, and especially the United States (U.S.), is deemed unacceptable, impeaching both electricity system managers and responsible politicians—e.g., California's 2000-01 electricity crisis initiates the 2003 recall election, defeating the incumbent Governor, Gray Davis.

The U.S. is unavoidably reliant on electricity, which for most purposes, has no substitute. Electricity is essential for economic growth, public health, local safety, national security and general welfare. Consequently, in the short term, electricity prices in deregulated markets are inelastic, and can spike quite high. In addition, the transmission and distribution of a deregulated electricity system—the middle functions between generation and retail—are a natural monopoly. Consequently, a deregulated electricity system cannot be modeled like a piping, telecommunication or transportation system.

High electrical system reliability is crucial, because electricity demand varies continuously—i.e., by the time of day, day of the week, and season of the year. In addition, random weather conditions materially alter the amount of electricity demanded and the ability to satisfy that demand. Also, sudden unforeseen losses of major generators or transmission lines significantly reduce the ability to meet demand requirements. Within this volatile environment, technical constraints necessitate an instantaneous and continuous balancing of electricity supply with demand—thus the need for adequate capacity reserves to ensure a highly reliable U.S. electrical system.

U.S. electrical system reliability is a high priority for electric utility executives—and justifies their holding an electric utility license—because innocent human lives are at risk. Deregulation of U.S.

electric utilities is promoted with the promise to maintain high U.S. electrical system reliability standards, which are the benchmarks for the world.

Electricity is defined as a "public good." Consequently, electricity markets cannot send correct price signals; as a result, electricity markets are inefficient. "Capacity markets" are paying generators for practically nothing. "Energy only" and "capacity markets" are not working as intended, which is to maintain a highly reliable electrical system, either in the U.S. or overseas. "Capacity markets" and markets in general are inefficient, and may be manipulated. Demand response and behind-the-meter generation programs are recommended to increase electricity reserve margins, but are facing resistance from commercial and industrial users.

The goal of this paper is to test if the promised U.S. electrical system high reliability standards are being maintained, once states deregulate their electric utilities. This research is the first in the literature to combine the 15 states and the District of Columbia (deregulated states), that have deregulated their electric utilities, with North American Electric Reliability Corporation (NERC) (2013) reserve margin forecasts, from 2014-2023, to analyze whether deregulated retail-choice states are adding adequate generating capacity to meet demand, and thus, maintain high electrical system reliability, when compared to the U.S. as a whole. This paper's results on electrical system reliability in the deregulated states are timely and important for U.S. electricity energy policy.

Additionally, this is the first paper in the literature to propose a Minkowski Space business model that adequately addresses the complex, multidiscipline, multidimensional, space-time U.S. electrical system deregulated market—in order to help set a U.S. electricity energy policy that achieves a highly reliable U.S. electrical system in the deregulated states, over a 10-year planning horizon. Future research will specify the Minkowski Space business model's mathematical formulation.

2. Literature Review

Cepeda and Finon (2011) explain that electrical generation adequacy and supply reliability are a "public good." Generation capacity is an "externality," where external costs exist and therefore, electricity's value does not derive solely from a competitive market. Consequently, price signals from competitive electricity markets are incorrect, and therefore, electricity markets are inefficient. "Capacity markets" are inadequate to produce sufficient electrical capacity reserve margins, when using the current U.S. electricity market deregulation energy policy.

Batlle, et al. (2007) explains that "capacity markets" in Spain are expensive—giving generators payments for practically nothing—and do not accomplish their intended purpose, which is: 1) guaranteeing new electricity capacity availability, thus ensuring electrical system reliability ; and 2) encouraging generators to make a special effort to supply demand, during an unexpected crisis. Instead of the current "capacity market," Batlle presents alternate design enhancements, meant to achieve a minimum capacity reserve margin, using a capacity definition based on the Loss of Load Probability (LOLP). The aim is to select a capacity definition that identifies exactly when a generating plant is needed, and a probabilistic reserve margin calculation model, thus giving generators timely incentives to ensure system reliability.

Kleit and Michaels (2013) point out that "capacity markets" do not exist for any commodity or good—other than electricity. The authors determine that capacity payments are unwarranted subsidies to electricity generators. Old inefficient generating units, that should have been mothballed, are instead kept in service, and little is done to build new plants. The current design of "capacity markets" is vastly more complex than required, because it includes all electricity generators—and industrial customers who can reduce their electricity demand requirements rapidly—instead of only a select subset of generators. In addition, it is determined that capacity prices are not determined by the market, but instead, by generator executives employing "demand curve" analysis, and then manipulating the forward auctions. Consequently, the theoretical case for existing "capacity markets" is unsubstantiated by the evidence. Instead, problems with capacity availability, which exists normally for no more than 100-to-200 hours per year, should be resolved using a subset consisting only of peaking generators, rather than including all generating facilities in the solution set.

Pat Wood III, one of the primary creators of the Electric Reliability Council of Texas' (ERCOT's) "energy only" market in 2000, and the past head of the Federal Energy Regulatory Commission (FERC) and the Public Utility Commission of Texas, makes the case for demand-side management programs, including conservation, appliance energy efficiency regulations and especially, demand response (DR)—in order to meet peak demand requirements (Axford, 2013). Wood says this would condition consumers to think about and use DR, thus benefiting from recently installed home smart-meters. DR gives residential electricity customers the option to agree to have their power curtailed for 20 minutes at a time, during the hottest part of the day, when marginal electricity prices are spiking, in exchange for compensation. However, weighing "retail choice and generator competition" versus "lower electricity prices and reliable service," it is believed residential consumers would prefer the later.

The Federal Energy Regulatory Commission reports that nationally, demand response (DR) reduction is about seven percent of peak load requirements, but may be reaching its limit of effectiveness (Opalka, 2012). If the necessity to curtail electrical load occurs frequently, financial incentives are not enough for commercial and industrial electricity users to interrupt their operations, and by so doing, abandon client commitments, and thereby risk jeopardizing the firm's livelihood. Attracting new clients is much more expensive than maintaining good customer relations. Considering how many risky factors businesses have to deal with, electricity should not be one of them. Instead, on-site, behind-the-meter generation could supply the necessary peaking capacity, using renewable energy solar panels or small gas-fired turbines.

The Brattle Group (2014) prepares a report for the Electric Reliability Council of Texas (ERCOT) to determine the "economically optimal" reserve margin, by balancing the costs of constructing new generating plants versus costs of not having enough capacity to meet demand, when needed, resulting in rotational load shedding and other emergency events. Based on a risk-neutral, probability-weighted average cost, using 7,500 simulations, the minimum system cost occurs at a reserve margin of 10.2%. The reserve margin increases to 14.1%, to meet the U.S. traditional industry standard 0.1 Loss of Load Expectation (LOLE) target, which is higher than economically optimal—prior to including risk aversion and other considerations.

Prentis (2014a) statistically tests Texas Interconnection grid electricity prices, pre-and-post 2002 deregulation, relative to U.S. electricity prices—and uses energy emergency alerts and reserve margin forecasts to determine Texas' electrical system reliability. The goal is to test whether the Electric Reliability Council of Texas (ERCOT) is accomplishing its stated mission, "to ensure a reliable electric grid and efficient electricity market." Relative to U.S. electricity prices, electricity prices in Texas rise about four times faster after deregulation, than before deregulation, indicating the Texas Interconnection grid is very significantly less efficient, after deregulation. North American Electric Reliability Corporation (NERC) energy alerts show the Texas Interconnection grid is under mounting stress, and ERCOT forecasts Texas will drop below the reserve margin standard of 13.75%, starting in 2015 and running through 2023. After deregulation, based on the very significant increase in relative electricity prices and lower reliability evidence, ERCOT is failing in its stated mission. Presented reforms will help ensure the market-based design U.S. electricity energy policy succeeds.

The Public Utility Commission of Texas (PUCT) is considering setting a mandatory reserve margin standard, rather than simply recommending a 13.75% voluntary reserve margin, to reduce the prospect of rotational load shedding or a total cascading blackout in the Texas Interconnection grid, because of inadequate generation capacity or deficient transmission infrastructure. This has precedent—in all other U.S. Interconnection grids, in 2007, the North American Electric Reliability Corporation (NERC) (2012), with oversight and approval of the Federal Energy Regulatory Commission (FERC), changes from voluntary to mandatory reserve margin compliance requirements, using industry-developed reliability standards. The expected PUCT mandatory directive should increase reserve margins in Texas, which are forecast by NERC to drop dangerously low, to 9.34% by 2018 and to 4.43% by 2023. However, critics call this the first step in introducing "capacity markets" in Texas, currently an "energy-only" state. Detractors consider "capacity markets" an "energy tax" on consumers that do little to ensure system reliability.

Prentis (2014b) uses means testing to statistically analyze electricity prices, from 1970-2011, for states that have effectively deregulated their electric utilities, relative to U.S. electricity prices, in order to establish whether deregulated electricity utility states are more or less efficient—after deregulation. Electricity prices in the effectively deregulated states increase over four times faster, after deregulation, relative to U.S. electricity prices, than before deregulation. Eight states have either extremely or very statistically significant increases in relative electricity prices and are extremely or very less efficient, after deregulation. No effectively deregulated state is significantly more efficient, after deregulation. The evidence shows that electric utility deregulation and retail choice "free market" competition do not naturally achieve lower prices, in the electric power industry. Without a meaningful change in current U.S. electricity energy policy, no new states should deregulate their electric utilities.

3. Data, Methodology and Empirical Findings

The U.S. Energy Information Administration (EIA) (2014) identifies the 15 states plus the District of Columbia (D.C.) (deregulated states) that replace their regulated electric utilities, to offer consumers retail choice from competing electrical generators: shown in Table 1.

Table 1. Fifteen States and D.C.—With Deregulated Electric Utilities, Offering Consumers Electricity Retail Choice

Fifteen States and D.C. with Deregulated Electric Utilities,—Offering Consumer Retail Choice in Competitive Markets
Connecticut
Delaware
Illinois
Maine
Maryland
Massachusetts
Michigan
New Hampshire
New Jersey
New York
Ohio
Oregon
Pennsylvania
Rhode Island
Texas
District of Columbia (D.C.)

The 15 states and the D.C. that deregulate their electric utilities and offer consumers retail choice in competitive markets.

The North American Electric Reliability Corporation (NERC) (2013) is the Electric Reliability Organization (ERO) for North America, and prepares the 2013 Long-Term Reliability Assessment (LTRA)—to evaluate the adequacy and long-term (10-year) reliability of the bulk power system (BPS) in North America. NERC forecasts, from 2014-2023, U.S. reserve margins using 18 U.S. Assessment Areas: shown in Table 2.

This research's methodology is to combine the U.S. Energy Information Administration's (EIA's) (2014) list of the 15 states and the District of Columbia that have deregulated their electric utilities, giving consumers retail choice of electricity supplied by competing sellers, with North American Electric Reliability Corporation (NERC) (2013) reserve margin forecasts, from 2014-to-2023, for the 18 NERC U.S. Assessment Areas, as indicated in the 2013 Long-Term Reliability Assessment (LTRA). This will determine whether electricity utility deregulation is reducing the capacity and reliability of the electrical system, in any of the 18 NERC U.S. Assessment Areas that include deregulated states—when compared to the reliability of the overall U.S. electricity system.

The combination of the 18 NERC U.S. Assessment Areas, with the 15 states and the District of Columbia that deregulate their electric utilities, indicates that six out of 18 NERC U.S. Assessment Areas contain deregulated states: shown in Table 3.

Table 2. North American Electric Reliability Corporation (NERC)— 18 United States Assessment Areas

NERC—18 U.S. Assessment Areas
Texas Reliability Entity - Electric Reliability Council of Texas (TRE-ERCOT)
Mid-Continent Independent System Operator (MISO)
Florida Reliability Coordinating Council (FRCC)
Mid-Continent Area Power Pool (MAPP)
Northeast Power Coordinating Council (NPCC) - New England (ISO-NE)
Northeast Power Coordinating Council (NPCC) - New York (NYISO)
PJM Interconnection
SERC Reliability Corporation (SERC)-East
SERC Reliability Corporation (SERC)-North
SERC Reliability Corporation (SERC)-Southeast
SERC Reliability Corporation (SERC)-West
Southwest Power Pool Regional Entity (SPP)
Western Electricity Coordinating Council (WECC)-California North (CALN)
Western Electricity Coordinating Council (WECC)-California South (CALS)
Western Electricity Coordinating Council (WECC)-Northwest U.S. (NORW)
Western Electricity Coordinating Council (WECC)-Basin (BASN)
Western Electricity Coordinating Council (WECC)-Desert Southwest (DSW)
Western Electricity Coordinating Council (WECC)-Rockies (ROCK)

NERC—18 Assessment Areas in the United States (U.S.), adapted in 2011.

Table 3. Combined EIA & NERC Information, Showing the Six out of 18 NERC U.S. Assessment Areas that include the 15 states and the District of Columbia, which Deregulate Their Electric Utilities

NERC – The Six NERC U.S. Assessment Areas that Include the Deregulated 15 states and the District of Columbia	Electricity Consumer Retail Choice, Deregulated 15 states and the District of Columbia that are included in each of the Six NERC U.S. Assessment Areas
TRE-ERCOT	Texas
MISO[1]	Michigan & Illinois
NPCC-New York (NYISO)	New York
NPCC-New England (ISO-NE)[2]	Connecticut, Maine, Massachusetts, New Hampshire & Rhode Island
PJM Interconnection[3]	Pennsylvania, New Jersey, Maryland, Ohio, Delaware & District of Columbia (D.C.)
WECC-NORW[4]	Oregon

[1] Includes: Wisconsin, Minnesota, Missouri, Iowa & Indiana.
[2] Includes: Vermont.
[3] Includes: Virginia & West Virginia.
[4] Includes: Montana & Washington.

The North American Electric Reliability Corporation (NERC) (2013) 2014-to-2023 forecast of reserve margins, from the 2013 Long-Term Reliability Assessment (LTRA), for the six NERC U.S. Assessment Areas, which include the deregulated 15 states and the District of Columbia, and total reserve margin forecasts for the entire U.S., represented by the 18 NERC U.S. Assessment Areas (AA), are shown in Table 4. Reference reserve margins, listed beneath Assessment Area names in Table 4, are the NERC mandatory reference reserve margin standards for that U.S. Assessment Area, which NERC expects the Assessment Areas to maintain. If forecast reserve margins, over the 10-year planning horizon, fall below reference reserve margin (RRM) standards in an Assessment Area, in any year from 2014-2023, this is shown using four asterisks in Table 4, and is an indicator that generating capacity is not being added fast enough in these Assessment Areas to keep up with electrical demand.

Table 4. NERC Forecast of Reserve Margins for the Six NERC Assessment Areas that Include the Deregulated 15 states and the District of Columbia. Percentages by year, shown with four asterisks, identify the Four of the Six Assessment Areas that are failing to meet NERC Reference Reserve Margin Standards, from 2014-2023.

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
TRE-ERCOT[1] **** RRM[3] 13.75%	13.74% ****	11.59% ****	10.34% ****	10.46% ****	9.34% ****	7.36% ****	6.44% ****	5.91% ****	5.11% ****	4.43% ****
MISO[1] **** RRM 14.2%	18.28%	12.13% ****	7.00% ****	6.29% ****	5.54% ****	4.86% ****	5.65% ****	4.90% ****	4.16% ****	3.44% ****
NPCC-New England (ISO-NE)[1] **** RRM 13.85%	29.02%	24.70%	22.39%	16.12%	15.36%	14.64%	14.02%	13.30% ****	12.69% ****	12.07% ****
NPCC-New York (NYISO)[1] **** RRM 17.0%	22.71%	21,22%	19.75%	18.85%	17.89%	16.85% ****	15.77% ****	14.73% ****	13.83% ****	13.03% ****
PJM Interconn. ** RRM 15.9%	30.86%	24.93%	23.40%	22.67%	21.39%	21.07%	19.66%	18.30%	17.11%	15.93% **
WECC-NORW RRM 17.48%	33.94%	N/A	N/A	N/A	33.54%	N/A	N/A	N/A	N/A	24.27%
Total: 18 U.S. AA[2] RRM 14.94%	27.52%	N/A	N/A	N/A	20.24%	N/A	N/A	N/A	N/A	15.38%

[1] The four asterisks identify the four NERC U.S. Assessment Areas failing to meet NERC Reference Reserve Margin Standards, shown by year, from 2014-2023.When forecast reserve margins drop below the North American Electric Reliability Corporation (NERC) reference reserve margin standards, in a NERC Assessment Area, it is signified in Table 4 with four asterisks in the year that it occurs.

[2] NERC forecast reserve margin totals, from 2014-2023, include all 18 NERC U.S. Assessment Areas (AA), which are a weighted average from Summary Tables G, I and K. The reported forecast reserve margins, from 2014-2023, are calculated using the anticipated reserve margin equation, from Table VII: Reserve Margins. Reference reserve margin (RRM) for all 18 NERC U.S. Assessment Areas (AA) is a weighted average from Summary Table G.

[3] The reference reserve margin (RRM) for the Texas Interconnect grid is voluntary.

The North American Electric Reliability Corporation (NERC) (2013) forecast reserve margins, for the TRE-ERCOT Assessment Area, fall below the NERC reference reserve margin standard of 13.75%, over the entire 10-year forecast period, from 2014-2013. NERC forecasts the

MISO Assessment Area will drop below the NERC reference reserve margin standard of 14.2%, during the summer of 2015, and extend through 2023. In addition, NERC determines that MISO forecast reserve margins could be further reduced, because of changing regulatory and economic factors that are unique to MISO. The NPCC-New England (ISO-NE) Assessment Area will underperform the NERC reference reserve margin standard of 13.85%, beginning in 2021 and continuing for the next two years. The NPCC-New York (NYISO) Assessment Area will fall below the NERC reference reserve margin standard of 17.00%, beginning in 2019 and extending through 2023.

The PMJ Interconnection Assessment Area forecast reserve margin, of 15.93% in 2023, comes very close to falling below the NERC reference reserve margin standard of 15.9%, which is represented by two asterisks on Table 4. Only the WECC-NORW Assessment Area stays comfortably above the NERC reference reserve margin standard of 17.48%, which may be because of the high percentage of hydroelectric power in the Pacific Northwest.

Four of the six NERC U.S. Assessment Areas, shown with four asterisks in Table 4, that include the deregulated 15 states and D.C., are not meeting North American Electric Reliability Corporation (NERC) reference reserve margin standards, and may be considered unreliable. Two Assessment Areas, TRE-ERCOT and MISO, are of special concern to the North American Electric Reliability Corporation (NERC), because their forecast reserve margins significantly underperform NERC reference reserve margin standards, over the 10-year planning horizon. Totals of all 18 NERC U.S. Assessment Area forecast reserve margins, from 2014 through 2023, remain above the NERC reference reserve margin standard of 14.94%.

It is clear that electric utility deregulation is negatively affecting adding generating capacity and maintaining high U.S. electrical system reliability, in the deregulated 15 states and the District of Columbia. Additional capital expenditures for power plant capacity in the deregulated states are needed—or the likelihood of rotational load shedding and system-wide blackouts will increase. The question is: who will supply the additional capital to build new plant capacity—generators, using their profits, or electricity consumers?

4. Discussion

Investors do not behave like regulators, and will not maintain, much less construct new generating capacity, until they are convinced that long-term electricity prices are headed much higher (Križanič and Oplotnik, 2013). Unfortunately, under the market-based system, the timing of adding new facilities is delayed, causing reserve margins to drop dangerously low—raising the possibility of rotational load shedding and cascading system blackouts—which will produce social condemnation and political upheaval.

To help supply sufficient electrical capacity to meet demand, in the deregulated states, Independent System Operators (ISOs) may use "capacity markets," in addition to "energy only" markets. "Capacity markets" are "forward, auctions, designed to make it profitable for generators to build new capacity, at a specific time and at reasonable cost, thus increasing system reliability (James, 2013). Unfortunately, this is not occurring in practice. Generators receive forward payments based on their total generating capacity, irrespective of when capacity is added to the grid. Consequently, payments simply go to existing facilities, and do not promote new plant construction. The question is always—when will the new electrical generating capacity come online? A primary concern is timing.

Electricity derivatives, such as futures and options, used by hedgers and speculators (Prentis, 2007), deal with capacity timing issues, but are ineffective. "Energy only" markets determine what plants currently operate—and "capacity markets" determine future plant availability. However, that determination is separated by as many as 10 years—because of siting, engineering, design, construction, startup and environmental licensing requirements. Consequently, it is impossible to optimize generation reliability using a dysfunctional "capacity market" design. This is the vital question, demanding resolution; best solved using a new business model, which will help set a revised U.S. electricity deregulation energy policy—thus ensuring a highly reliable U.S. electrical system over a 10-year planning horizon.

Based on the evidence, assuming markets in general are efficient is proven incorrect, when the appropriate data are tested (Prentis, 2011, 2012). In addition, markets in general may be manipulated (Prentis, 2013). The current artificial construct of an electricity wholesale market and retail market permits price manipulation using "economic withholding" (Johnston, 2014) and "rent extraction" (Griffith, 2008). For example, price caps are a halfway measure, between regulatory controls and deregulated electricity markets, protecting residential consumers against spiking electricity prices, but materially distort the market.

The move from a vertically integrated, regulated monopoly, public electric utility model—with average cost of production pricing, which is less than monopoly pricing—transitions to a privatized and deregulated electricity market model—with marginal cost of production pricing and unregulated monopolist pricing (Fatima and Barik, 2012). Because of market design deficiencies, different questions and answers are needed to successfully design the deregulated U.S. electricity market. To help set U.S. electricity energy policy that ensures high U.S. electrical system reliability, a new business model that adequately addresses the deregulated electric utility market is needed.

Electricity is unlike any other commodity, which may be described as a vector, with the following dimensions; 1) power—an indication of capacity availability, measured in megawatts (MW); and 2) energy—metered use, measured in megawatt hours (MWh). Both are essential for electrical system reliability. However, energy is the only interest to electricity users. Everything else merely supports energy supply.

In physics, without understanding multidimensional concepts, such as:—scalar vs. vector, distance vs. displacement, speed vs. velocity, and correctly specifying the positive and negative acceleration of physical objects through time—the U.S. would not have successfully made it to the moon, and back. To correct the current U.S. electricity energy policy timing weaknesses, in the deregulated U.S. electricity markets, a new business model of the deregulated electric power system is proposed, using a multidisciplinary (Chase and Prentis, 1987) and a multidimensional, space-time solution approach (Prentis, 1987).

Attaining success in the business requires understanding multidimensional concepts; best accomplished using a four-dimensional space-time model. The four dimensions are: 1) market requirement; 2) product/service position; 3) management activities—i.e., effectively and efficiently managing the transformation process for goods and services, by adding value, all while remaining flexible and adjusting to dynamic conditions. This requires precisely specifying and realistically modeling human nature; and 4) time: short-term constraints vs. long-term requirements/opportunities (Prentis, 1987).

Realistically modeling human nature necessitates recognizing that people are highly intelligent strategic agents, capable of interacting freely with the outside world. People learn independently, modify their own and others' behavior, all while possessing and exercising free will. People can be incentivized or motivated through religion, morality, human relations, money, recognition and advancement. However, people are in some way unique, and their thoughts and actions cannot be accurately controlled or predicted.

Open markets admit everyone; including those who are fiercely independent or antisocial. As a result, these persons may be irrational, self-destructive, malicious, and act unlawfully. Like preparing for the 100-year flood—in business, anticipate probabilities, but write and enforce laws and regulations to control psychopathic behavior—fit punishment to the crime.

In physics, the empirical evidence from Michelson–Morley type experiments, occurring during the late 19th and very-early 20th centuries, show there is an absolute—the speed of light—measured by time, which is always the same, irrespective of the position and relative speed of the observer. This puzzling natural phenomenon is what Albert Einstein set out to understand and explain in his 1905 paper on the special theory of relativity, entitled: "On the Electrodynamics of Moving Bodies." Einstein's theory recognizes the speed of light is an absolute that never changes. Consequently, space and time reality changes, in order to accommodate a fixed light speed. As a result of Einstein's theory, space and time is forever linked, and neither time nor space can be understood or defined separately.

Hermann Minkowski was Einstein's mathematics professor. Minkowski Space is used to mathematically model and explain Einstein's general theory of relativity (Petkov, 2012). In Minkowski Space, the three standard dimensions of space are joined with the single dimension of time, to construct a four-dimensional manifold that represents space-time. Time can speed up or slow down and distances can stretch or shrink, depending on different speeds and gravitational pulls, for different people, in different positions, relative to one another. Moreover, and perhaps the most difficult to comprehend, in Minkowski Space, the division of time into "past, present, and future" is considered an illusion—because all space and all time form an indivisible whole—called space-time.

Minkowski Space is proposed as the best way to represent and mathematically solve the four-dimensional space-time business model. For our purposes, Minkowski Space is applied in business and is not solely a physical model. The Minkowski Space business model is of a social institution, large or small, that includes objective truths, external to the individual, and subjective truths, internal to the individual, both positive and negative (Prentis, 2006). Any perceived change within the model is not just physical, but can be mental. Perception of what is hoped for can take on the guise or reality, and can modify one's beliefs and therefore, "what, how and why" something is being discussed—including one's positioning in the model.

In this application of Minkowski Space to business, there is a self-evident social science axiom:*" The only thing that doesn't change—is change itself."* Change is an absolute, but only on one level. Social science includes faith, and *"The more things change, the more they stay the same."* Outward change does not ultimately affect the core morality and profound reality of a person's existence—through time. This is the "paradox of change," permitting meanings on different levels (Prentis, 2013).

In business, there are no absolutes, not even the absolute of change. Asking the correct questions, imagination, creativity, money and politics are the major limits. Consequently, *"a good idea whose time has come"*—not money—is the ultimate force for change. However, money is politically important—and used by powerful advocacy groups to set-up think-tanks and policy-or-research-institutes that hire creative people to pursue the agendas of those who fund these organizations.

One change to Minkowski Space, for the business model, will be to assume a "past, present and future," with time traveling in one direction—the positive direction. The past or historical event can influence the present and the future, however taking new action in the past is impossible—consequently, new action may occur in the present, and as an expected or unexpected event in the future. Please note, this does not stop unscrupulous persons from being propagandizing revisionists and rewriting history, to create fictitious more favorable past events and reasons, to benefit themselves—and pledging to do everything expected of them, initially, however, they never actually intend to fulfill those promises, in the future.

Del Monte (2012) uses Minkowski Space—because it is adaptable—to express the relationship between "time, existence and energy." Minkowski Space has the following four coordinates:

$$x, y, z, ict \tag{1}$$

where:

x, y and z are the 3 spatial coordinates, and;

$i = \sqrt{-1}$ (i.e., the square root of -1, which is an imaginary number)

c = the speed of light in a vacuum

t = sequence of events, as measured by a clock.

Minkowski Space is defined by a set of four mutually orthogonal vectors; the mathematics is available in the literature (Petkov, 2012). Most find Minkowski Space difficult to comprehend, even Einstein complains of its complexity. Nonetheless, for our purposes, the important Minkowski Space point to remember is—space-time is intertwined, in a single, inseparable interlocking continuum. To help develop the Minkowski Space mathematical model application to business, project management scope/time/cost trade-off methods will be used, which are necessary when implementing a new, complex transformation process, in all goods and service industries (Prentis, 1989).

5. Conclusions and Policy Implications

The goal of this paper is to test if the promised U.S. electrical system high reliability standards are being maintained, once states deregulate their electric utilities—and to propose a new multidiscipline, multidimensional, space-time business model, to help set a U.S. electricity deregulation energy policy that achieves a highly reliable U.S. electrical system in the deregulated states, over a 10-year planning horizon.

For the first time in the literature, U.S. Energy Information Administration (EIA) (2014) information, on the 15 states and the District of Columbia that have deregulated their electric utilities, is combined with the North American Electric Reliability Corporation (NERC) (2013) 2014-to-2023 reserve margin forecasts, in the 18 NERC U.S. Assessment Areas, to analyze whether deregulated retail-choice states are adding adequate generating capacity to meet demand, and thus, maintain high electrical system reliability, when compared to the U.S. as a whole.

Four of the six NERC U.S. Assessment Areas, that include the deregulated 15 states and D.C., are not meeting NERC reference reserve margin standards and may be considered unreliable. When taken together, the 18 NERC U.S. Assessment Areas remain above the NERC reference reserve margin standard of 14.94%.

It is clear that electric utility deregulation is negatively affecting adding generating capacity and maintaining high U.S. electrical system reliability, in the deregulated 15 states and District of Columbia. "Energy only" and "capacity markets" are failing to work as intended, which is to maintain high U.S. electrical system reliability in the deregulated market states. Deteriorating U.S. electrical system reliability in deregulated states indicates that without a meaningful change in current U.S. electricity energy policy, no new states should deregulate their electric utilities. A new design of electricity markets is required, so they will achieve high U.S. electrical system reliability, in all of the 15 states and the District of Columbia, which currently allow consumers retail choice.

Applying Minkowski Space to a business model should adequately address the complex, multidiscipline, multidimensional, space-time U.S. electrical system deregulated market. The Minkowski Space business model's mathematical formulation will be specified in future research—with the goal to help revise the U.S. electricity deregulation energy policy, so that it achieves a highly reliable U.S. electrical system in the deregulated states, over a 10-year planning horizon.

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