



Nikola Power Patent Portfolio

The Nikola Power Story

Nikola Power was founded in 2017 by Jonathan W. Postal (J.W.), a veteran in the distributed generation industry, to capitalize on the projected growth of the energy storage industry and to expand the penetration of clean energy projects across North America through the integration of best-in-class software tools. The backbone of the company's software is the acquisition of the intellectual property and physical assets of American Electric Vehicles (AEV), a company founded in 2007 by Dr. Dan Rivers and Dr. Bruce Johnson.

AEV, based in Colorado Springs, was an early leader in battery system management in the burgeoning electric vehicle space. In order to improve performance, cycle life, and power output, Dr. Rivers turned to a young Stanford-trained professor, Dr. Gregory Plett, just down the road at the University of Colorado, Colorado Springs. Dr. Plett's work was based on physics-based algorithms and models to more accurately predict and manage lithium-ion battery systems. The algorithms examine battery lifespan and performance at a cellular level and leverage real-world, real-time data to provide more useful inputs for operational and financial decisions made by the end user. While initially developed for vehicle applications, the opportunity to use this technology for stationary, grid-tied energy storage was quite apparent.

These algorithms provide the intellectual framework for the development of Nikola Power's battery management and energy management systems — tools that will enable energy storage asset owners to better manage and utilize a battery asset: stacking additional revenue streams such as energy trading, while effectively serving its primary function of resiliency, peak shaving, or frequency regulation.

After completing a \$1.5M seed round in Q4 2017, Nikola Power is building a suite of tools based on its four patented algorithms. It will also develop clean energy projects in energy storage and solar in an effort to build a world powered 100% by renewable energy.

Energy Storage Management Software

As the energy storage industry matures, cutting edge energy storage system software will be required to provide a growing number of services depending on the specific application, technology, and market condition. Balancing this complexity will require sophisticated analytic and system control capabilities to improve operations that will:

- Maximize asset utilization based on market and system conditions, and
- Manage the cycle life operations to optimize the asset life.

As a result, software will play an increasingly important role in reducing both capital and operating costs, and maximizing system value as the industry continues to evolve.

In addition to creating a competitive advantage in battery dispatch optimization for multiple, and sometimes competing, storage services, more analytically sophisticated software can also



greatly improve the safety of a storage system by more precisely monitoring and managing the operational characteristics of the batteries down to the battery cell level. Obtaining higher asset utilization, together with more granular battery analytics and safety protocols, will become a significant market differentiator and an important source of improved financial returns.

Importance of Battery Management Systems

To date, battery management systems (BMS) have largely been developed and implemented by battery manufacturers whose economic incentives have not always been directly aligned with those of the long-term asset owners and operators. The battery manufacturers' and inverter suppliers' interests have largely been circumscribed by the equipment's functional parameters – operating protocols and guidelines necessary to ensure that the equipment is operated within prescribed technical and safety limits. The ability to optimize the storage system to increase economic value has largely been subjugated to their primary objective of designing a battery system with ample overcapacity to buffer the equipment against premature aging.

Nikola Power is developing battery management software that can do both: ensuring batteries are operated within the manufacturers' prescribed technical specifications, and simultaneously optimizing the performance of the batteries to maximize economic value.

Nikola Power's patented battery management algorithms can more accurately manage lithium-ion battery systems, at the cell, pack, and system level, thereby significantly increasing performance per unit of capacity, cycle life, battery system efficiency, and safety. As a result, it can create a very attractive competitive advantage in the market for stationary storage services.

The Nikola Power Advantage

Most BMS technology uses simple, generic computer algorithms to monitor and control the battery pack. Nikola's patented BMS algorithms use heuristic, adaptive, real-time estimation methods that can significantly enhance battery performance. The following table summarizes the advantages of Nikola BMS algorithms with first-generation, conventional algorithms:



	Nikola BMS Algorithms	Conventional BMS Algorithms	Advantages & Outcomes
Battery Cell Modeling	Empirically Based Calculations based on real-world, real-time battery performance	Ad Hoc Based on curves that fit to a limited and static data sets	Nikola's approach mitigates aging while simultaneously enhancing performance
Logic / Reasoning	Heuristic Based on data and measurable outcomes Employs probabilistic analyses	Deductive Based on inference Subject to cognitive bias	Produces empirical results rather than logical conclusions
Statistical Methodology	Adaptive: algorithms adapt through iterative learning from ongoing data collection	Non-Adaptive: statistical tests and methodologies are predetermined and static	Predictive analytics yield much greater accuracy and statistical certainty

Nikola Patent Status

Nikola has four key patent disclosures and granted patents specifically addressing the control of large battery packs for electric vehicles and stationary storage energy applications as follows:

- AEV-8 "System and method for recursively estimating battery cell total capacity." Patent 8,041,522 issued 10/18/2011.
- AEV-10 "System and method for maximizing a battery pack total energy metric." Patent 8,918,299 granted 12/23/2014.
- AEV-11 "System and method for equalizing a battery pack during a battery pack charging process." Patent 8,427,105 granted 4/23/2013.
- AEV-6 "System and method for efficient adaptive joint estimation of battery cell state-of-charge, resistance, and available energy." Filed 2/3/2009. US Patent Application 12/660,150 Filed 02/19/2010. In process.

These patents are the first four in Nikola Power's IP collection. These patents address the key issues of availability, safety, energy, life, and performance.

Availability and Safety

The first two patent disclosures ensure timely identification of specific battery cells that are underperforming or failing, allowing operations to be conducted with maximum safety and minimum service interruption for maintenance.



“System and method for efficient adaptive joint estimation of battery cell state-of-charge, resistance, and available energy.”

This algorithm returns cell level state-of-charge (SOC) efficiently (i.e. without excessive complexity and attendant processor power) and with high accuracy near the SOC end points of 0% and 100%. This is crucial since most of the wear experienced by a cell is in the 10% bands near the end points. The algorithm also provides the associated cell resistance and energy estimates. These results are achieved without bias caused by cell polarization voltages.

“System and method for recursively estimating battery cell total capacity.”

A battery cell's total capacity tends to degrade over time as the cell wears out. Having an accurate capacity estimate allows maximum utilization of the cell and, therefore, of a battery pack composed of battery cells. Such state-of-health (SOH) estimates provide the basis for optimized maintenance and service procedures.

Energy and Life

The third patent is used to calculate true pack level SOC to allow maximum energy storage consistent with optimum life.

“System and method for maximizing a battery pack total energy metric.”

Battery cells are characterized in terms of capacity (measured in Ampere-hours) but the energy stored in a cell (measured in Watt-hours) determines its ability to do work. This algorithm determines the battery pack configuration that maximizes the pack's total energy metric by dropping, or ignoring, weak cells, thereby allowing its optimal use in a particular application.

Performance

The fourth patent provides for equalization of the cells in a battery string to ensure optimum pack performance.

“System and method for equalizing a battery pack during a battery pack charging process.”

The traditional approach of equalizing cell voltages in a battery pack is suboptimal due to cell non-linearity and differences in cell capacities. This algorithm optimizes an equalization metric during charging only, thereby simplifying the equalization and allowing optimal use of the battery pack in its application. This predictive approach to equalization is simpler and more cost effective than active balancing schemes.



Expanding Battery Management Capabilities

Nikola Power intends to expand its patent collection with new IP to optimize the battery management software to provide multiple battery storage services for customer groups in specific markets. We intend to create dispatch and cycling algorithms that maximize asset utilization for the storage services that can be provided for specific customer segments in different geographic markets. The following table provides an example of the types of storage services that can be provided simultaneously for customers using a single storage system. This “stacking” of revenue streams will create higher asset utilization and produce better project financial returns.

Electric Energy Storage Services	System Size	Discharge Duration	Cycles/Year
Utilities			
Electric Supply Capacity (Replace Expensive Peak Generators)	5 - 250 MW	2 - 6 hours	< 100
Transmission Upgrade Deferral	10 - 100 MW	2 - 8 hours	10 - 50
Distribution Upgrade Deferral	500 kW - 10 MW	1 - 4 hours	10 - 50
Demand Charge Management	500 kW - 10 MW	1 - 4 hours	50 - 500
Ancillary Services (Frequency Regulation, Voltage Support)	10 - 50 MW	15 - 60 minutes	250 - 10,000
Wind and Solar Developers			
Electric Supply Capacity (Shaped or Firm Product)	5 - 250 MW	2 - 6 hours	100 - 300
Ancillary Services (Frequency Regulation, Voltage Support)	10 - 50 MW	15 - 60 minutes	250 - 10,000
Commercial and Industrial Energy Management			
Demand Charge Management	100 kW - 10 MW	10 sec - 15 minutes	10 - 200
Power Quality and Reliability	50 kW - 10 MW	1 - 4 hours	50 - 500
Merchant Wholesale Power Market			
Electric Energy Time-Shift (Arbitrage)	10 - 100 MW	≤ 1 hour	> 200
Ancillary Services (Frequency Regulation, Voltage Support)	10 - 50 MW	15- 60 minutes	250 - 10,000



Partnering with the University of Colorado

The aforementioned patents were authored by Professor Gregory Plett of the University of Colorado's High-Capacity Battery Research and Test Laboratory located in Colorado Springs, CO, and under the direction of Dr. Daniel D. Rivers when Dr. Rivers was CEO of American Electric Vehicles Corporation. Nikola Power has an ongoing consulting and advisory relationship with Professor Plett for both guidance and advice. In addition, Nikola Power will work with the University of Colorado on any future IP Dr. Plett may develop on its behalf. Dr. Rivers currently serves as the Nikola Power's Chief Technology Officer and Board Member.

Dr. Plett earned his Ph.D. at Stanford University in computer systems engineering specializing in real-time estimation and control theory, including modern variations of extended Kalman filtering. This background uniquely qualified him for battery management system algorithm development. Now a tenured professor at the University of Colorado, Dr. Plett has attracted significant grant funding to the university and established the High-Capacity Battery Research and Test Laboratory, one of the world's leading authorities in advanced battery management testing and controls. His research and consulting work has been supported by General Motors, LG Chem Power Inc. (supplier of the Chevy Volt battery pack,) and the Department of Energy in partnership with Ford Motor Company.



Professor Greg Plett

Industry Pioneers

Dr. Dan Rivers and Dr. Greg Plett began their collaboration in advanced battery management system identification and control in the spring of 2001, when Dr. Rivers had just founded LG Chem Compact Power, Inc. Dr. Plett's groundbreaking work has given rise to some 25 patent disclosures, and supported the industry leading electric vehicle development for LG Chem Ltd., the U.S. Advanced Battery Consortium ("USABC"), Ford Motor Company, General Motors, and Chrysler, as well as drive systems developed for electric vehicle applications for the U.S. Air Force, and a commercial all-electric shuttle bus developed in China.

Today, LG Chem supplies lithium-ion batteries or cells to over 20 manufacturers of hybrid and pure electric vehicles worldwide, making it the world's second leading electric vehicle battery supplier with a 24% market share (Lux Research, 8/18/2017). Its batteries are used in the Chevy Volt hybrid EV, the Chevy Bolt EV, the Nissan LEAF EV, the Chrysler Pacifica hybrid, the Ford Focus EV, and others.



Appendix: Resumes

JONATHAN W. POSTAL – CHIEF EXECUTIVE OFFICER, NIKOLA POWER

J.W. has been a driving force behind multiple innovative companies in the renewable energy industry. He founded Nikola Power and led the formation of the company through its seed round while positioning it for future growth and success. He was also a co-founder of Main Street Power, a pioneer in the distributed generation power purchase agreement space and an innovator in clean energy finance. While at Main Street Power, J.W. spearheaded the first New Market and Investment Tax Credit portfolio in the country. J.W. has also served as an executive, Chief Development Officer, and Chief Operating Officer with Milender White Construction, SunShare, and Clean Energy Collective respectively.

J.W. is a leader in clean energy in Colorado and across the country. He has worked on trailblazing legislation for distributed solar, community solar, and renewable energy finance and has traveled the country developing solar projects in AZ, CA, CO, MA, MN, NJ, NM, SC, and TX. He has been a frequent speaker at industry events around the nation for topics such as clean energy finance, community solar, and now solar + storage and entrepreneurship.

J.W. spent 13 years in the investment management business prior to co-founding Main Street Power in 2008. He spent ten years at A.G. Edwards and three years in an independent firm he started with a partner and built a respected national fiduciary practice with over \$500M under management. J.W. graduated from the University of Colorado with BA in History and has an MA from Georgetown in Public Policy.

DR. DANIEL D. RIVERS – CHIEF TECHNOLOGY OFFICER, NIKOLA POWER

Dan has 40 years of experience in research, design, management, and execution of high technology commercial and military programs in the fields of batteries, power electronics, motors, electric vehicles, and RF and IR systems. Dan was the Tier 1 program manager for the General Motors EV1 electric car power train subsystem. He co-founded and led Enova Systems (OTCQB:ENVS.) and LG Chem Power Inc. (originally Compact Power, Inc., "CPI"), and directed the initial work leading to the LGCPI-GM contract for the Chevrolet Volt battery pack. He also co-founded and led American Electric Vehicles (AEV). Dan earned his Ph.D. in mathematics at UCLA.

DR. GREGORY L. PLETT – SPECIAL ADVISOR, NIKOLA POWER

Dr. Plett has over 15 years of experience in design, implementation, and validation of battery-management systems and has written two textbooks on the subject. His expertise includes methods to determine battery state of charge, state of health, available energy, and available power. As Professor of Electrical and Computer Engineering, he leads a research team at the University of Colorado - Colorado Springs (UCCS) investigating emerging new battery-control methods that promise more performance and longer life; he also manages the High-Capacity Battery Research and Test Laboratory at UCCS. Dr. Plett received his Ph.D. in Electrical Engineering from Stanford University.

