**Accomplishment A:**

**Soft-switching Technology:** Dr. Batarseh has made fundamental contributions to research, development and commercialization of soft-switching dc-dc converters. He was the first to introduce the detailed analysis of high order resonant converters including the well-known LLC topology; introduced the generalized state-plane diagram for analysis/design of higher order resonant converters. Sample publications: [“Operation mode analysis and peak gain approximation of the LLC resonant converter” IEEE Tran. on power electronics 27 (4), pp. 1985-1995, 2011][ “Generalized Approach to the Small Signal Modeling of DC-to-DC Resonant Converters,” IEEE Trans. on Aerospace and Electronic Systems, Vol. 29, No. 3, pp. 894-909, 1993] US Patents: #7,646,116, #7,149,096, #6,906,931, #6,982,887. This work alone created 3 license agreements with companies.

**Accomplishment B:**

**Commercialization of Microinverter:** Dr. Batarseh has made many original contributions to the development and commercialization of the first high efficiency, high power density, single-phase microinverters. This work resulted in numerous publications, patents, license agreements and the launching of his start-up company Petra Solar (now Patra Systems). His contributions are covered by a number of publications: [US Patents: #9,071,150; #9,722,427; # 9,473,044; #8,552,286]; [ “A Single-Stage Micro-Inverter without Using Electrolytic capacitors,” IEEE Trans. on Power Electronics, Vol. 28, No. 6, pp. 2677-2687, 2012]; In 2007, Petra Systems licensed 9 US patents: [7,646,116; 7,583,128; 7,471,524; 7,388,761; 7,251,113;7,196,916;7,149,096; 6,982,887; 6,906,931)], raised $54 million in VC funding, and executed the world’s first and largest pole-mount PV solar project with New Jersey’s largest utility PSE&G: [<https://gigaom.com/2009/07/29/petra-solar-inks-deal-with-new-jersey-utility-for-worlds-largest-pole-solar-project/>]

**Accomplishment C:**

## **Commercialization of high-power density DC-DC Converters:** Dr. Batarseh has made fundamental contributions to the new class of high-power density DC-DC converters that led to new product line commercialized by ASTEC Power USA including a new class of 1/8th interleaved DC-DC bricks and the world’s first 1/16 DC-DC brick with the new record of highest efficiency. This work is covered under four US/international patents and several publications: [US Patent: #7,149,096, “Power converter with interleaved topology”]; [US Patent: # US6982887 ”DC-DC converter with coupled-inductors current-doubler”]; [US Patent: #6906931, “Zero-voltage switching half-bridge DC-DC converter topology by utilizing the transformer leakage inductance trapped energy “]; [World Patent: #WO/2006/009576: “Dynamic Optimization of Efficiency Using Dead Time and FET Drive Control], where new coupled-inductor based-on compact, efficient design and multi-layer design, current-doubler topology, interleaved soft-switching control methods dc-dc converters were developed, designed, prototyped and commercialized.

**Accomplishment D:**

## **Novel Energy Transfer Concept:** In collaboration with NASA, Dr. Batarseh led the development of the first single-stage, single-switch class of power factor correction (PFC) unit with direct energy transfer. This work covered under two patents, a licensed agreement and several publications: [Two US Patents: #6,819,575: “AC/DC switch mode power supply with PFC using direct energy transfer concept“; #6,636,430: Energy Transfer Concept in AC/DC converter with unity PF; #US6970364B2 “Low cost AC/DC converter with power factor correction”]. His new concept led to an innovative way to directly transfer energy from the input to the output, resulting in significant efficiency improvement. The flyboost cell automatically limits the DC bus voltage through flyboost transformer turn ratio. This concept was highly read and led to the development of a class of AC-DC PFC circuits, that were patented and later assigned to a private company.

**Accomplishment E:**

**Developing the three-phase Microinverter:** Through funding from the US DoE, Dr. Batarseh led the development of the world’s first three-phase microinverter with highest power density and increased efficiency to 98% by inventing and developing a new two-stage conversion with unique control methodology, active grid-interaction to support PV firming, load shifting, and peak shaving. The research findings were covered in 10 IEEE Trans. papers and several patents. [US patents # 9,473,044, 9,484,840] and IEEE Transaction papers.["Dynamic Dead Time Optimization and Phase-Skipping Control Techniques for Three-Phase Micro-Inverter Applications," IEEE Trans. on Industrial Electronics, vol. 63, no. 12, pp. 7523-7532, 2016]. He presented for the first time the idea of phase-skipping control in three-phase microinverter resulting in peak efficiency of 98%. This patent was licensed to the private sector [Press Release:

<https://www.ucf.edu/news/cleantech-incubator-licenses-ucf-developed-industrys-first-single-module-three-phase-microinverter-for-solar-energy-systems/>]

**Accomplishment F:**

**Commercialization the first hybrid microinverter**: Dr. Batarseh made original contributions to the development of multi-port PV system utilizing soft-switching LLC integrated storage dc-coupled system. Bidirectional power flow control between any two ports is achieved by utilizing advanced PWM methods with embedded optimization algorithm for tracking highest efficiency over complete power flow range. In 2019, he developed multi-port utilizes the multilevel architecture by using flying capacitor GaN-based converter, PV and battery integration at a DC coupled common bus. His contributions have been covered in several publications, two US patents and one license: US Patents # 11,682,983 “A GaN-Based Multiport Multilevel Converter/Inverter”, 2023; #10,630,190: Multi-input single-resonant tank LLC converter, 2020. IEEE-PELS Magazine article [ “Emerging Opportunities in Distributed Power Electronics and Battery Integration-setting the stage for an energy storage revolution,” Vol. 7, No. 2, pp.22-32, 2020].

**Accomplishment G:**

**High power density converter:** With funding from the US Army, Air Force and NASA, Dr. Batarseh developed the world’s highest power density (11.4 kW/liter) high-power dc-dc converter with soft-switching and interleaved integrated topology with jet cooling system for the Army’s first generation of compact Hybrid/Electric Vehicles. He introduced the first parallel multi-bus and multi-channel, bi-directional, single-stage DC-DC converters with high efficiency and power density to reduce the total satellite power system mass. The work has been reported in several patents and a large number of publications: [US Patent #7646116 “Method and system for balancing power distribution in DC to DC power conversion (2009)]; [“Modeling and Control of Three-Port DC/DC Converter Interface for Satellite Applications,” IEEE Trans. on Power Electronics, Vol.25,no.3, pp.637-649,2010]. The technology has been commercialized by ApECOR.com corporation.

**Accomplishment H:**

In 2003, ASTEC Power Corp. sponsored multimillion research R&D grant with Dr. Batarseh’s lab to develop new DC-DC power module to support ASTEC’s new product line. Over three years, he led the development of a new class of 1/8th interleaved DC-DC bricks and the world’s first 1/16 DC-DC brick with the highest efficiency and power density. By using alternated duty cycle control to achieve soft-switching for all switches, his team developed new innovative interleaved DC-DC topologies with coupled-inductor and current-doubler, with optimized digital control algorithm to dynamically optimize converter parameters such as dead-time and switching frequency under variable operating conditions. The new design resulted in highest efficiency and fastest transient response units. ASTEC Power released DTX series products as the industry’s first all-digital DC/DC (isolated) converter with highest conversion efficiency. ASTEC extended the technology to the 1/4th and 16th brick power module products to converters became part of ASTEC product line.

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Since establishing the Florida Power Electronics Center in 1998, the center rapidly gained a reputation as one of the most respected energy research centers in the U.S. His commercialization success is demonstrated by his licensed patents, and the spin-off companies he launched: Petra Systems, Advanced Power Electronics Corp (ApECOR), and Tech-e-book.

Dr. Batarsh’s work on soft-switching DC-DC and DC-AC converters has created new market segments of solar AC microinverter modules and new product lines of dc-dc converters. In 2006, Dr. Batarseh’s contributions resulted in the first ever development and commercialized grid-tied microinverter with a PV panel level DC-to-AC inverter (AC module). From conception to implementation, the AC PV-module was designed and commercialized with capabilities to inject power back into the grid to improve its quality. This unique architecture increased the overall energy harnessed by PV module, resulting in a safe, more efficient, and compact inverter design with reduced balance of system costs. The new microinverter without electrolytic capacitor designs have revolutionized the solar energy sector by improving the reliability and safety of distributed solar energy systems.

Based on his novel and licensed microinverter patents, Dr. Batarseh founded Petra Solar (renamed Petra Systems) with his students that commercialized the first smart-grid interactive microinverter-based solar power system. Followed with Department of Energy (DoE) sponsorship, he led the development of the world’s first three-phase microinverter with high power density and 98% efficiency through a novel two-stage conversion with unique control methodology and soft switching technology. The new design supports active grid-interaction to meet the utility requirements by providing functionalities such as VAR compensation and frequency and voltage control. This patented and licensed technology (US patent #9,473,044) presented for the first time the idea of phase-skipping control to enhance performance.

In 2003, ASTEC Power Corp. sponsored multimillion research R&D grant with Dr. Batarseh’s lab to develop new DC-DC power module to support ASTEC’s new product line. Over three years, he led the development of a new class of 1/8th interleaved DC-DC bricks and the world’s first 1/16 DC-DC brick with the highest efficiency and power density. By using alternated duty cycle control to achieve soft-switching for all switches, his team developed new innovative interleaved DC-DC topologies with coupled-inductor and current-doubler, with optimized digital control algorithm to dynamically optimize converter parameters such as dead-time and switching frequency under variable operating conditions. The new design resulted in highest efficiency and fastest transient response units. ASTEC Power released DTX series products as the industry’s first all-digital DC/DC (isolated) converter with highest conversion efficiency. ASTEC extended the technology to the 1/4th and 16th brick power module products to converters became part of ASTEC product line.

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Dr. Batarseh has made original contributions to the development of a multi-port PV system with energy storage His innovative designs incorporate a soft-switching LLC integrated with energy storage, resulting in a highly compact dc-coupled configuration. Bidirectional power flow between any two ports is achieved by utilizing advanced PWM with an embedded optimization algorithm for tracking the highest efficiency over full power range. He recently developed the multi-port converter utilizing the multilevel architecture by using a flying capacitor and GaN switches for PV and battery integration at a DC-coupled common bus.

For his contributions, Dr. Batarseh has won several global and national prestigious recognitions.

**TECHNICAL, PROFESSIONAL, SOCIETAL AND/OR ECONOMIC IMPACT OF CONTRIBUTIONS.**

*This is a required field. This section should specifically describe the long-term impact of the contributions and accomplishments described in Section 7 of this application. Space is limited to 3,000 characters (approximately 400 words). Space is limited to 400 words.*

Dr. Batarseh’s sustained impact on power electronics spans 30 years, resulted in a rich and high quality of scholarly work. Thirty of his patents have been licensed to six companies (Power Supply Concepts, IP Ventures, Petra Systems, MaxHarvest Microinverters, Tech-E-Book, and Protium Power Systems) for the commercialization of the smart single-phase and three-phase microinverters, LED controllers, high-power density dc-dc, and smart solar chargers.

ASTEC Power released DTX series products as the industry’s first all-digital DC/DC (isolated) converter with highest conversion efficiency. The first offering, the DTX42K48, with a footprint approximately the size of an industry-standard eighth brick and just 5 mm high (world’s smallest), delivers up to 50 watts at 0.96-1.44 V from a 36-75 V input for OEM designers seeking the performance and flexibility of an all-digital approach (control, monitoring, and power conversion circuitry). The estimated revenue from those products alone exceeds $40M.

Dr. Batarseh’s company Petra Systems secured $54 million in venture capital funding to design and manufacture the first smart grid microinverter-based solar system to harvest solar power, monitor the grid, and provide localized light control with grid reliability. His AC PV module design has been commercially validated by the manufacture and installation of more than 10 million microinverters by several companies worldwide. For example, the company installed 40 MW on 200,000 electric poles in New Jersey, and 7MW of smart PV systems in Bahrain, United Arab Emirates, and Jordan, 5MW of PV systems on 230,000 poles in the U.S. Virgin Islands. These technological innovations have impacted the lives and livelihoods of people in developing countries by providing clean, inexpensive, and inexhaustible energy while creating hundreds of jobs in the process.

In 2003, Dr. Batarseh founded ApECOR and developed the world's smallest and most efficient solar charger for military batteries with thousands of these smart solar chargers are deployed today globally by the U.S. military.

In 2022, Protium Power Systems, Inc (PPS) signed a license agreement to commercialize his first-ever grid-tied hybrid microinverter, seamlessly integrated with battery storage—all mounted at the back of the PV module. This development has generated considerable interest, and PPS has successfully raised its initial startup funds. The fully integrated modular system anticipated to reshape the landscape of affordable, scalable grid-tied hybrid microinverters and energy access solutions.

Based on his pioneering contributions in research and commercialization, I strongly believe Dr. Batarseh is highly qualified for the IEEE Newel award.