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EPRO PE - 001	Power Factor Improvement in Modified Bridgeless Landsman Converter Fed EV Battery Charger

This work deals with the design and implementation of a new charger for a battery-operated electric vehicle (EV) with power factor improvement at the front end. In the proposed configuration, the conventional diode converter at the source end of existing EV battery charger is eliminated with the modified Landsman power factor correction (PFC) converter. The PFC converter is cascaded to a flyback isolated converter, which yields the EV battery control to charge it, first in constant current mode then switching to constant voltage mode. The proposed PFC converter is controlled using single sensed entity to achieve the robust regulation of dc-link voltage as well as to ensure the unity power factor operation. The proposed topology offers improved power quality, low device stress, and low input and output current ripple with low input current harmonics when compared to the conventional one. Moreover, to demonstrate the conformity of the proposed charger to an IEC 61000-3-2 standard, a prototype is built and tested to charge a 48 V EV battery of 100 Ah capacity, under transients in input voltage. The performance of the charger is found satisfactory for all the cases.

EPRO PE - 002	Implementation of a novel Hybrid UPQC topology endowed with an Isolated Bi-Directional DC-DC Converter at DC link

This paper introduces an original hybrid unified power quality conditioner (HUPQC) topology as an alternative solution to electrical power quality problems. The proposed HUPQC consists of the shunt hybrid active power filter (SHAPF), the dynamic voltage restorer (DVR) and the isolated bi-directional DC-DC converter (BiDC) located at the common DC link. The SHAPF enables reduction in the voltage rating of the DC link capacitor, helps to reduce the cost and the size of the DC link and hence reduces switching losses of the voltage source inverter (VSI). Besides the novelty of its topology, dynamic reactive power compensation capability is realized for the first time in literature within HUPQC concept by achieving adaptively controlling DC link voltage. The BiDC not only provides isolation and bi-directional power flow between the DVR and the SHAPF but also operates to keep the DC link voltage of DVR constant against adaptively changing DC link voltage of the SHAPF. In addition to these, a new hybrid voltage sag/swell detection algorithm based on the combination of the improved clarke transformation and the enhanced phase-locked loop is developed and introduced. In order to verify the viability and effectiveness of the proposed HUPQC topology, experimental studies are carried out.

EPRO PE – 003	LQR Control of Single-Phase Grid-Tied PUC5 Inverter with LCL Filter

This paper presents the current control design procedure of a single-phase grid-tied 5-level Packed U-Cell inverter (PUC5) with LCL output filter. The PUC5 inverter is used as an interface of renewable energy sources like solar applications. The LCL filter is calculated according to the grid-tied operation and converter ratings. An optimal controller, based on linear quadratic regulator with integral action (LQRI), is designed to inject a sinusoidal current with low harmonic distortion at unity power factor. Required to that design, the PUC5 inverter is modelled in D-Q frame. The sensor-less voltage control is incorporated into the switching technique to balance the PUC5 capacitor voltage and generate 5-level waveform at the output. Experimental tests are performed on a laboratory benchmark to confirm the theoretical design. The results prove the efficiency and accuracy of the adopted control strategy in steady state and under transients of grid current, grid inductance, AC and DC voltage amplitudes.

EPRO PE - 004	A Cooperative Adaptive Droop Based Energy Management & Optimal Voltage Regulation Scheme for DC Microgrids

This paper presents an adaptive droop based cooperative energy management scheme for a PV battery based autonomous DC microgrid. To overcome the basic challenges in managing multiple batteries in a distributed DC network, a cooperative cyber network is employed to formulate an enhanced adaptive droop control philosophy. With PV panels operating as a constant power source at MPPT, battery energy storage systems (BESSs) cooperate among themselves to balance state-of-charge(SoC) between them and undergo constant voltage (CV) charging mode when the condition arises, which is handled using the proposed adaptive droop concept. Further emphasis is given on optimal voltage regulation to induce robustness against time-delay as compared to the conventional voltage observers, which cause high observing error. Moreover, the design criteria of the proposed strategy is provided to ensure system stability under normal and time-delayed conditions. The proposed control strategy is simulated in MATLAB/SIMULINK environment to demonstrate SoC balancing, CV charging albeit various communication issues such as delay and multiple link failure. The proposed strategy is further tested on a FPGA based experimental prototype to validate the effectiveness of the proposed strategy.

EPRO PE - 005	Solar PV Energy Generation System Interfaced to Three Phase Grid with Improved Power Quality

This work deals with a multipurpose DS (Distributed Sparse) control approach for a single stage solar photovoltaic (PV) energy generation system (SPEGS). This SPEGS is interfaced here to the three phase grid at varying solar irradiance and compensating the nonlinear load tied at point of common interconnection. The SPEGS performs multitasks. It feeds the generated solar PV power to the local three phase grid. It reduces the harmonics of loads and furnished a balanced currents of local three-phase grid. The SPEGS uses a solar PV array, a voltage source converter, a nonlinear load, a three phase grid, DC-link capacitance. In case, when the solar irradiance is not available, the proposed system works as DSTATCOM (Distribution Static Compensator) by utilizing same VSC (Voltage Source Converter). For extracting maximum power from the PV source, the traditional P&O (Perturb and Observe) scheme is utilized here. The tracking performance and efficiency of P&O technique, are also examined here at rapid changing climatic conditions to show behavior of P&O scheme. The DS control approach is capable to estimate required fundamental component to find out reference grid currents. The proposed control approach is validated on a developed prototype in the laboratory.

EPRO PE - 006	A Family of Ćuk-, Zeta-, and SEPIC-based Soft Switching DC-DC Converters

In this paper, a new class of dc-dc converter topologies based on capacitive link dc-dc converters-Cuk, SEPIC, and Zeta converters-that operate under the critical conduction mode has been proposed. The proposed converters are the extensions of quasi-square-wave zero-current-switching converters, which use an auxiliary circuit to provide zero-current and zero-voltage switching for all semiconductor switches at both turn-on and turn-off transitions and eliminate voltage ringing across the output switch. Using the proposed auxiliary circuit, the value of dv/dt has been diminished, hence, the EMI of the proposed topology is significantly reduced compared to the conventional quasi-square-wave zero-current-switching converters. To verify the operation of the proposed converter and confirm its advantages, an experimental prototype has been implemented, and the experimental results and the efficiency of the proposed converter have been compared with the conventional quasi-square-wave zero-current-switching converters.

EPRO PE - 007	An Inductive Power Transfer Converter with High Efficiency throughout Battery Charging Process

An inductive power transfer (IPT) converter usually has an optimum efficiency only at a matched load. Due to wide load range variation during battery charging, it is challenging for an IPT converter to achieve the required output and maintain high efficiency throughout the charging process. In this paper, a series-series compensated IPT (SSIPT) converter with an active rectifier is analyzed and implemented for battery charging. Appropriate operations are employed for constant current (CC) charging and constant voltage (CV) charging. A novel operation approach is proposed to achieve constant output voltage and ensure load impedance matching during CV charging without the help of an extra DC-DC converter which incurs loss. Both a frequency modulated primary inverter and a phase angle modulated secondary active rectifier can achieve soft switching. High efficiency can be maintained during the whole battery charging profile.

EPRO PE - 008	Single Phase Bidirectional H6 Rectifier/Inverter

Transformer-less photovoltaic (PV) inverters are more widely adopted due to high efficiency, low cost and light weight, etc. However, H5, HERIC, etc. transformer-less PV inverters do not have the bidirectional capability for solar energy storage system in the future. With topology derivation history reviewed from rectifier to inverter, the essence of bidirectional rectifier/inverter is revealed to find a reverse power flow approach. Therefore, this paper proposes an advanced bidirectional technique for a selected H6 inverter topology with only modulation strategy modified, while the others remain the same. For the H6 circuitry in both rectifier and inverter modes, excellent three level DM voltage feature is achieved, while leakage current issue is eliminated at the same time with improved modulation method. Simulations and experimental results verify the proposed single phase bidirectional H6 rectifier/inverter technique.

EPRO PE - 009	Voltage Modulated Direct Power Control for a Weak Grid-Connected Voltage Source Inverters

In this paper, we design a voltage modulated direct power control (VM-DPC) for a three-phase voltage source inverter (VSI) connected to a weak grid, where the PLL system may make the system unstable if the conventional vector current control (VCC) method is applied. Compared with the conventional VCC method, the main advantage of the proposed VM-DPC method is that the PLL system is eliminated. Moreover, in order to inject the rated real power to the weak grid, the VSI system should generate some certain amount of reactive power as well. An eigenvalues based analysis shows the system with the proposed method tracks its desired dynamics in the certain operating range. Both simulation and experimental results match the theoretical expectations closely.

EPRO PE – 010	A new non-isolated low-power inductor less piezoelectric DC-DC converter

A new non-isolated low-power inductorless piezoelectric resonant converter is presented. The piezoelectric material is used as an energy storage element like an inductance in a classical Buck-Boost power electronic converter. As opposed to most existing piezoelectric converters, the proposed topology enables to dynamically adjust the output power and ratio keeping a high efficiency for a large range of output powers and for a large range of conversion ratios taking advantage of piezoelectric high quality factor and achieving zero voltage switching. A theoretical analysis of the step-up converter using an energetic approach is introduced and enables a fast and reliable pre-design of the piezoelectric component. This analysis is in perfect agreement with the simulation model performed on Matlab/Simulink. For a given piezoelectric resonator both analytical and simulation models provide very high efficiencies for different output powers. The converter is tested experimentally with a 10 V input voltage using the piezoelectric radial resonance mode. An efficiency higher than 98% for a 160 mW power conversion was achieved, decreasing slowly to 78% at 1.4 W. For a large range of voltage gains, the efficiency remains higher than 90% up to an output power of 750 mW. The experimental results are in perfect agreement with the theoretical analysis until 500 mW.

EPRO PE – 011	An Improved Single-Stage PFC AC/DC Power Supply

This letter describes an enhancement to a previously reported single-stage transformer-leakage-inductance-based power-factor-corrected isolated power supply. An improved switch timing calculation algorithm is developed to achieve zero current switch on of the active rectifier switches. The algorithm is based on an analytical model of the system relating the gate timing to the input and output voltages and control inputs. Remarkably, a closed-form expression for the switch timing can be derived and used to calculate and apply the timings in real time without the need for high-speed measurements or resonant structures. A prototype 1.25 kW prototype power supply is implemented using the proposed technique and performance measurements presented.

EPRO PE - 012	LMMN Based Adaptive Control for Power Quality Improvement of Grid Intertie Wind-PV System

A new topology comprising of wind turbine driven synchronous generator (SG) and solar photovoltaic (PV) array for renewable energy harvesting, is proposed in this work. The stochastic inputs for proposed system, are agitated by the nonlinear time dependent parameters such as variable wind speed and changing solar insolation. The speed variations are absorbed using back to back interfaced power electronic converters (PECs) namely synchronous generator side converter (SGC) and utility grid side converter (UGC) with a common DC link where solar PV array is tied directly. The power injection into the utility grid, is levelled by the optimal utilization of PECs. The SGC uses vector control (VC) for speed control of SG and maintains unity power factor (UPF) at stator terminals. UGC acquires its switching pulses with proper application of least mean mixed norm (LMMN) control technique. The new application of LMMN control scheme is used for harmonics compensation and fundamental load component extraction. The DC link voltage is regulated using proportional integral (PI) controller. A prototype is developed and tested under different conditions of sudden changes in load, wind velocity variations as well as under varying solar PV insolation. The power sharing scheme proves to be effective. The power quality (PQ) issues are also addressed and mitigated effectively. The performance is exhibited for the validation of the proposed system and its control.

EPRO PE - 013	A Bidirectional CDT-LC Resonant DC–DC Converter with a Wide Voltage Range

A novel high conversion ratio bidirectional C-dual transformers-LC (CDT-LC) resonant DC-DC converter is proposed in this paper. Based on the traditional LLC, an auxiliary transformer and an extra resonant capacitance are employed in CDT-LC structure. It not only harvests high efficiency but exhibits a good voltage gain feature. Especially for the case of light load, CDT-LC still harvests a high efficiency, compared with traditional converters. Also, it can achieves a fast gain reduction when the switching frequency is higher than resonant frequency. In this paper, the operating principles of the converter are analyzed in both bi-directional operation modes. In additional, its dual-transformers structure feature and voltage gain characteristics are discussed in details. Furthermore, the parameter design method is provided. Moreover, the loss breakdown for the converter is given in details. At last, a 2.5kW prototype is established to verify the performance of the CDT-LC converter, and its maximum efficiency reaches 97%.

EPRO PE - 014	Bidirectional DC-DC Converter for Modular Residential Battery Energy Storage Systems

A novel bidirectional dc-dc converter based on the quasi-Z-source (qZS) topology is presented. During battery discharge, it operates as the conventional qZS full-bridge converter with a synchronous voltage doubler rectifier. During battery charging, it operates as the half-bridge converter with a synchronous full-bridge rectifier and LC-filter. A relay is used for reconfiguration between those two modes. The operation principle is explained, and design guidelines are provided. A prototype with a nominal power of 300 W is used for verification of steady-state regulation characteristics and efficiency measurements in the input voltage range compatible with an eight-cell LiFePO4 battery. Closed loop control system for the converter application in dc microgrids is presented and tested in two control scenarios: dc-bus signaling and direct reference defined by a master controller through a communication channel.

EPRO PE - 015	Active Power Flow Control between DC Microgrids

The interconnection of dc microgrids may help to address the problems associated with uncertainty of renewable energy generation systems. In this paper, a Load Flow Converter (LFC) is proposed which interconnects two adjacent dc microgrids and controls bidirectional power flow between them. The LFC needs to regulate power by applying and controlling a voltage in between two dc grids. Generation of this series-voltage, if done by using the same grids, will be of immense advantage. Therefore, a new concept of input-parallel and output-series connection is proposed. The LFC is formed with a Dual Active Bridge (DAB) followed by a full-bridge dc-dc converter. It injects dynamic voltage in series with the transmission line to control power flow between the dc grids. The required power rating of the LFC is fairly low compared to the power transmitted between dc grids and also it does not require any external power source for operation. The proposed configuration is simulated in MATLAB/OPAL-RT based real-time simulation platform. A scaled-down version of the system (at 30V level) is developed in the laboratory to experimentally validate the concept. The results show the effectiveness of the LFC for interconnection of dc microgrids.

EPRO PE - 016	High Step-Up Y-source Coupled-Inductor Impedance Network Boost DC-DC Converters with Common Ground and Continuous Input Current

High step-up Y-source coupled-inductor impedance network boost DC-DC converter with common ground and continuous input current is presented in this paper. The proposed converter has added auxiliary diodes and capacitors to three-winding Y-shape coupled inductor cells to constitute the current conduction path and realize the voltage-double function. Compared to other magnetically coupled boost converters, the proposed converter can produce the higher voltage gain with more degrees of freedom in winding match. The same output gain can be obtained by using different winding turn ratios. Also, the proposed converter has a common ground and realizes the continuous input current. The corresponding topologies and steady operation principles are analyzed. The experimental results in a 300W prototype have verified the validity of the theoretical analysis.

EPRO PE - 017	Control Method for Overvoltage Suppression across the DC Capacitor in a Grid-Connection Converter Using Leg Short-Circuit of Power MOSFETs during the Initial Charge

This paper proposes a control method for the initial charge of the dc-capacitor in voltage-source power converters. The proposed method is suitable for the power converter equipped with a small dc capacitor and is capable of removing the initial charge circuit. The proposed method makes a leg short-circuit by using power devices employed in the power converter, discharges the dc capacitor and suppresses its overvoltage due to the initial charge. The short-circuit operation only occurs for a short time and is used once in each leg to distribute the loss to each power device. The experimental verification using a 200-V, 5-kVA three-phase converter shows that the proposed method can reduce the peak voltage of the dc capacitor from 520 V to 420 V. The experimental results exhibit a good capability of the proposed method to suppress the overvoltage due to initial charge without fatal damage to the power devices. As a result, the proposed enables removal of the initial charge circuit, resulting in a reduction in the size and cost of power converters.

EPRO PE - 018	An Interleaved Bi-directional AC-DC Converter with Reduced Switches and Reactive Power Control

In this paper, a new interleaved AC-DC converter with a reduced number of semiconductor components for high power energy storage applications is proposed. The interleaved structure reduces the AC side current ripple as well as increases the overall current rating. Moreover, the proposed switching pattern reduces switching and the developed controller provides reactive power control during both power flow directions. The proposed structure is simulated and analyzed using MATLAB/Simulink software, and a 3.5kW prototype of the system has been implemented in the Lab. The results confirm the performance of the proposed topology. There is a seamless transition between operation with different power factors and the current ripple is significantly reduced.

EPRO PE - 019	A Multilevel Distributed Hybrid Control Scheme for Islanded DC Microgrids

This paper proposes a multilevel hybrid control scheme, including grid control and node control, for an islanded 48-V solar photovoltaic-based low voltage dc microgrid that aims to overcome the drawbacks of centralized and decentralized control schemes. The analyzed microgrid includes a 35-kW rooftop solar system as the main power source at bus-1 with battery storage, 5-kW hybrid energy storage system (Vanadium Redox flow battery with super capacitor) at bus-2, and variable loads such as electrical vehicles at bus-3. In the case of a central failure, the proposed hybrid control scheme is capable of seamlessly switching between high bandwidth communication and low bandwidth communication channels of communications to implement a distributed control scheme. The central supervisory controller is responsible for updation of grid characteristics and sending/receiving information to/from local node controllers, which are responsible for bus voltage regulation and energy management. The control hierarchy features optimized and safe operation (charge and discharge) of storage devices in dc microgrids. The paper also demonstrates the application of battery-supercapacitor systems to absorb system transients during load changes. The simulation showcases the continuous flow of information and decision processes via each level of control while simultaneously taking into consideration the constraints of each subsystem.

EPRO PE - 020	Wide-Range ZVS Control Technique for Bidirectional Dual-Bridge Series Resonant dc-dc Converters

For high voltage and high power bidirectional dc-dc converters, soft-switching of all active power devices is mandatory to ensure high efficiency and reliability. This paper describes a control technique for wide-range zero-voltage switching (ZVS) implementation of dual-bridge series resonant dc-dc converters (DBSRCs). The proposed control technique integrates variable frequency modulation (VFM) and phase shift modulation (PSM), in which the former effectively achieves ZVS for both step-down and step-up operation, while the latter is employed to further extend power transmission capability. The proposed technique is built on the time-domain analysis of ZVS condition. A closedform solution is formulated which guarantees sufficient ZVS commutation current at switching instants, accounting for the presence of switches parasitic and/or snubber capacitances, while maintains the rms tank current at near-to-minimum levels. Compared with minimum rms current trajectory (MCT) modulation, lower switching losses, enhanced efficiency and mitigated voltage ringings are obtained. Effectiveness of the proposed technique is verified by means of a 800W experimental prototype. Closed-loop operation with the proposed VFM+PSM controller is also implemented and experimentally tested.

EPRO PE - 021	Soft-Switching Voltage-Demultiplier-Cell-Based High Step-Down DC–DC Converter

A novel high step-down DC-DC converter with voltage demultiplier cell is proposed in the paper, which is widely used in the high step-down applications such as electric vehicle and digital circuits. The combinational employment of switched-capacitor and coupled-inductor to build extended voltage demultiplier in the proposed converter, which makes a quite higher voltage conversion ratio than that of the existing counterparts. Thus, the proposed converter can achieve extremely low output voltage with an appropriate duty ratio, and the extreme duty cycle is avoided. Accordingly, voltage stress on power switches is greatly reduced. Then, MOSFETs with low conduction resistance could be utilized to reduce conduction loss. Importantly, zero-voltage switching could be achieved for the main switch, which promotes the conversion efficiency further. In addition, the coupled-inductor operates not only as a filter inductor, but also as a transformer when the main switch is in the OFF state, which reduces the volume of the magnetic core and improves the power density of the converter. The operation principle, performance analysis, design considerations of the proposed converter and performance comparison with recent counterparts are discussed in detail, and finally, an experimental prototype is built to verify the theoretical analysis and performance of the proposed converter.

EPRO PE - 022	Analysis of the Neutral Point Voltage Self-Balance Mechanism in the Three-Level Full-Bridge DC−DC Converter by Introduction of Flying Capacitors

The three-level full-bridge (TLFB) DC-DC converter has been widely used in high-voltage high-power applications. In the experimental test, the neutral point voltage deviation appears, moreover, it has also been found out that if the flying capacitors are introduced, the input capacitor voltages could realize self-balance even if no active balancing solutions are adopted. In the previous publications, the role of flying capacitors is generally considered to extend the range of soft switching, however, the self-balance ability has not been mentioned or investigated in any publications thus far. In order to fill this gap, this paper provides the detailed mode operation analysis of the TLFB converter and reveals the cause of the imbalance. In addition, the mechanism of the self-balance ability provided by the flying capacitors is explained in detail, which gives a deep insight into the converter. At last, the influence factor of the voltage error in steady state has been analyzed, and the specific expression of the voltage error is also derived. The feasibility of the theoretical analysis is verified by the simulation and experimental results.

EPRO PE - 023	A Novel Current Modulation Method to Eliminate Low Frequency Harmonics in Single-Stage Dual Active Bridge AC/DC Converter

The dual active bridge (DAB) topology is frequently preferred in industry as a dc-dc converter with various current modulation methods, such as, phase shift (PSM), trapezoidal (TZM), triangular (TRM), and hybrid methods. The TZM and TZM-TRM hybrid method can solve the current circulation problem of PSM, extend the zero voltage switching (ZVS) region to the full operating range, and thereby improve the light load efficiency. However, all these methods have been developed for a dc-dc converter, and cannot be directly applied to a single-stage DAB based ac-dc converter due to the low input voltage close to the zero crossing points of the grid, otherwise significant distortion is created. This paper analysis the line current distortion related with the modulation for a single-stage DAB based ac-dc converter and a novel hybrid current modulation (HCM) method which solves the distortion problem is proposed. However, since the HCM method increases the rms current as side effect, therefore the improved version iHCM method is developed and the distortion free current without increasing the rms current is obtained. The results obtained from the theoretical analysis are verified by an experimental prototype of 250W.

EPRO PE - 024	Phase-Shifted Full-Bridge DC-DC Converter with High Efficiency and High Power Density Using Center-Tapped Clamp Circuit for Battery Charging in Electric Vehicles

In this paper, a phase-shifted full-bridge converter employing a new center-tapped clamp circuit is proposed to achieve high efficiency and high power density in electric-vehicle battery charger applications. By using a simple center-tapped clamp circuit, which consists of two diodes and one capacitor, many limitations in conventional PSFB converters are solved. The proposed center-tapped clamp circuit provides the clamping path and allows the secondary voltage stress to be clamped to the secondary-reflected input voltage. This results in a greatly reduced conduction loss in the secondary full-bridge rectifier (FBR) due to the low forward-voltage drop of low voltage-rated diodes, and the resistor-capacitor-diode snubber loss is eliminated. In addition, the circulating current in the primary side is removed without any duty-cycle loss. Furthermore, the turn-off switching loss in the FBR is substantially reduced due to the decreased reverse-recovery current and the reduced reverse voltage. With these advantages, high efficiency can be achieved. Besides, the size of the output inductor is considerably reduced with the aid of clamping voltage, resulting in a high power density with saving the cost. In order to confirm the effectiveness of the proposed converter, a 3.3-kW prototype was tested. Experimental results show that the proposed converter achieves high efficiency over the entire conditions with high power density.

EPRO PE - 025	Performance Investigation of Multifunctional On-Grid Hybrid Wind-PV System with OASC and MAF Based Control

An observer based adaptive speed control (OASC) and a multistage adaptive filter (MAF) based control structure, are proposed for on-grid hybrid wind-photovoltaic (PV) system to deal with the two major issues such as peak wind power extraction and mitigation of power quality problems, respectively. The OASC is an adaptive control alongside exhibiting robustness against uncertainties (structured and unstructured). The objective of peak wind power extraction is met through cascaded control, which includes an inner hysteresis current control and an outer speed control based on OASC. The proposed OASC includes a disturbance observer loop with backstepping control. Moreover, it incorporates a discontinuous projection law based adaptive parameter estimation, thereby resulting in a sense of hybrid control implementation. The outer speed control loop provides the reference stator current to the inner loop retaining maximum power point tracking.Herein, the effects of nonlinear, balanced and unbalanced loads are addressed through the incorporation of vectorial approach for extracting fundamental positive sequence components from nonlinear load currents to realize harmonics free fundamental reference currents for the grid. The proposed controls are simulated and compared with the conventional techniques. The control implementation and performance testing, are carried out on the hybrid system built in the laboratory.

EPRO PE - 026	A High Efficiency Non-Isolated Buck-Boost Converter Based on ZETA Converter

In this paper, a new transformer less buck-boost converter based on ZETA converter is introduced. The proposed converter has the zeta converter advantages such as, buck-boost capability, input to output DC insulation and continuous output current. The suggested converter voltage gain is higher than the classic ZETA converter. In the presented converter, only one main switch is utilized. The proposed converter offers low voltage stress of the switch; therefore, the low on-state resistance of the main switch can be selected to decrease losses of the switch. The presented converter topology is simple; hence, the control of the converter is simple. The converter has the continuous output current. The mathematical analyses of the presented converter are given. The experimental results confirm the correctness of the analysis.

EPRO PE - 027	A New Three Phase Multi-Point Clamped 5LHPFC with Reduced PSD Count and Switch Stress

The trade-off between advantages and overall part count of classical multi-level converters are leading to an active interest on introducing a new topology with reduced power semiconductor devices (PSD) count. In this paper, a new multipoint clamped (MPC), three phase 5-level high power factor converter (5L-HPFC) is proposed. The converter can be modeled as a diode clamped converter with omission of clamping diodes. Impact of voltage stress on power semiconductor devices with two PWM strategies are studied and a methodology for reducing switch stress per each leg is presented. Comprehensive comparative analysis is carried out with existing topologies. The minimum value of normalized index makes the proposed topology is a suitable for medium voltage and high power applications. In addition, A new single band hysteresis current controller (SBHC) is proposed and compared with conventional single band and multi-band current control techniques for AC/DC power conversion applications. Further, the proposed topology with SBHC are investigated at following conditions: bidirectional power flow capability, supply unbalance, harmonics elimination and power factor correction. The validation of a new 5L-HPFC with proposed controlling scheme is verified with simulation and a down scaled experimental setup.

EPRO PE - 028	A Four-Switch Three-Phase AC-DC Converter with Galvanic Isolation

A new single stage three-phase AC-DC converter with four switches and galvanic isolation is proposed in this paper. The new converter is simple and uses fewer switches than previously proposed AC-DC converters of the same type. It is a bridgeless converter that can operate with continuous input current and with any PWM method suitable for a standard three-phase six-switch voltage source rectifier. In this paper, the operation, control, analysis and design of the proposed converter are explained and its features are discussed. Experimental results obtained from a prototype that confirm the feasibility of the converter are presented as well.

EPRO PE - 029	A Single-Stage Single-Switch Soft-Switching (S6) Boost-Fly back PFC Converter

This paper presents a S6 PFC converter to enhance the current shaping performance and reduce the total harmonic distortion (THD). This improvement is achieved by the aid of an auxiliary winding which is used to lower the input current harmonics and also achieve soft-switching condition. As a result, the switching losses are reduced and harmonic content of the input current is improved noticeably in comparison to the conventional S6 PFC converter. Also the total number of semiconductor elements is reduced in the proposed topology which results in lower cost and higher efficiency. The operating modes of the proposed converter are discussed in details and the design procedure is presented. A 200 kHz prototype of the proposed converter is implemented and the obtained results are provided to verify the converter theoretical analysis and operation.

EPRO PE - 030	Integrated Buck and Modified Push-Pull DC-DC Converter with High Step-Down Ratio

This paper proposes a novel isolated high step-down conversion circuit, called an integrated buck and modified push-pull (IBMPP) converter, which is able to lower the voltage level on the primary side of the ideal transformer, resulting in a lower turns-ratio and decreased leakage inductance. The IBMPP converter is able to prevent the duty cycle from operating in extremely low conditions. Furthermore, the proposed converter adopts active-clamp techniques to recycle leakage energy and to suppress voltage spikes, so that the conversion efficiency can be effectively improved. The advantages of the IBMPP converter are its simple topology, easy control mechanism (which requires only two signals with a 180-degree phase shift), high conversion ratio, low component counts for power switches, and less voltage stress on some of the switches on the high-voltage side. The operation principle, steady-state analysis, design considerations, and experimental results of the proposed IBMPP converter are presented in detail. The feasibility of the IBMPP is verified by hardware implementation. The full-load efficiency at 250W is 81.44%, and the input and output voltage are 380V and 5V, respectively.

EPRO PE - 031	Three-Phase Isolated Multi-Modular Converter in Renewable Energy Distribution Systems

Multilevel converters are widely used in medium and high voltage applications. Their high performance, power quality, efficiency and smaller filters make them interesting for renewable energy distribution systems. In utility- scale photovoltaic plants, these topologies could provide multiple benefits since they are able to connect string of photovoltaic panels to independent modules. However, high floating voltages caused by high number of modules limit multilevel converters in medium and high voltage applications, since all of them are not suitable to provide isolation to each module. To offer a solution, this paper presents a novel multi-modular converter that provides multiple isolated modules connected in series through low frequency transformers to operate at medium voltage levels. This topology is able to achieve the power balancing between the connected modules and independently adjust the dc voltage of each module by means of controlling a circulating current which flows through the arms. Furthermore, the topology implemented in photovoltaic renewable energy systems and the control strategy required to regulate the circulating and the output current are presented. The main principle behind this concept and the performance of the converter are evaluated and validated through simulation and experimental results.

EPRO PE - 032	Highly-Efficient Bridgeless Dual-Mode Resonant Single Power-Conversion AC-DC Converter

This paper presents a bridgeless dual-mode single power-conversion ac-dc converter that can achieve high conversion efficiency. By adopting a bidirectional switch, we remove a full-bridge diode rectifier from the grid side of the proposed converter and thereby reduce the number of components and the primary side conduction loss. To adapt the converter to 1-kW power applications with a bidirectional switch, we used a series resonant circuit in the output voltage doubler on the secondary side. The series resonant circuit also provides zero-current switching turn-off at the output diode, and thereby reduces the reverse-recovery loss. To attain medium-high power capability with an appropriate transformer, the proposed converter operates in both discontinuous conduction mode and continuous conduction mode. The operation principle of the converter is presented and analyzed. By using dual-mode control algorithm, the proposed converter achieves high power factor of 0.994 and maximum efficiency of 97.3 %. Experimental results for a prototype 1-kW ac-dc converter verify these characteristics.

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