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Unidirectional AC–DC PFC Converters for Power Quality Improvement

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ABSTRACT: This framework presents an adaptable control plan for unidirectional ac–dc support converters with the end goal of moderating matrix power quality. Since most power component revision circuits accessible in the business market use unidirectional ac–dc support converter topologies, this is a no-cost answer for repaying consonant present and receptive force in private applications. Harmonic current and reactive power compensation systems in the unidirectional ac–dc support converter are examined. The extra center of this paper is to measure the information current bends by the unidirectional ac–dc help converter utilized for supplying dynamic energy to the heap as well as receptive force. Because of information current contortions, the measure of receptive force infused from an individual converter to the framework ought to be limited. Trial results are exhibited to accept the viability of the proposed control system.

KEYWORDS: Active Power Filter [APF], Cusp Distortion, Harmonic Current Compensation [HCC], Power Factor Correction [PFC], Reactive Power Compensation [RPC], Unidirectional AC-DC Boost Converter

I. INTRODUCTION

Power quality investigation in AC power frameworks is worried with deviations of the voltage or current from the sought perfect sinusoid of steady adequacy and recurrence. Unfiltered harmonics cause impedances in other electric offices, making irregular and undesirable conduct of electrical hardware and transformer overheating. Uncontrolled responsive force expands transmission conduction misfortunes and break down the execution of voltage regulation. Consequently, it is sought to decrease these impacts through sufficient means, i.e., harmonic current compensation [HCC]. A few advancements, ordinarily having high power limits, in light of force gadgets hypothesis have planned to enhance lattice power quality and remunerate receptive force at the transmission and conveyance framework level.

Flexible Alternating Current Transmission Systems [FACTS] have been considered by mechanical and scholarly scientists since 1990s. Substituting current transmission frameworks fusing power hardware based compensators and other static controllers for the most part improve controllability and increment power exchange capacity. Among FACTS advances, the Static VAR Compensator [SVC], static synchronous compensator (STATCOM), and brought together power quality conditioner [UPQC] all have the ability to repay responsive force. Dynamic force channels [APFs] configurable with different force topologies can be used for enhancing power quality through HCC. In spite of the fact that SVCs, STATCOMs, UPQCs, and APFs display remarkable execution, they may not be the best answer for development of force nature of a whole power framework because of high capital and working expenses, and extra power misfortunes because of long separation transmission of receptive influence.

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To discover more conservative arrangements, the requests of force quality moderation have ceaselessly urged power gadgets designers to incorporate HCC capacities as auxiliary administrations in bidirectional force converters. As force converters for renewable vitality sources turn out to be more famous in AC power frameworks, the potential for HCC will increment, as these control plans can be utilized in existing topologies without equipment changes. In spite of the expanded utility and cost investment funds, the quantity of renewable force converters fit for satisfying these capacities is still restricted. Then again, Vehicle-to-Grid [V2G] innovation has as of late risen for joining of Electric Vehicles [EVs] into the electric lattice as vitality stockpiling units, which can give power quality alleviation as an auxiliary administration.

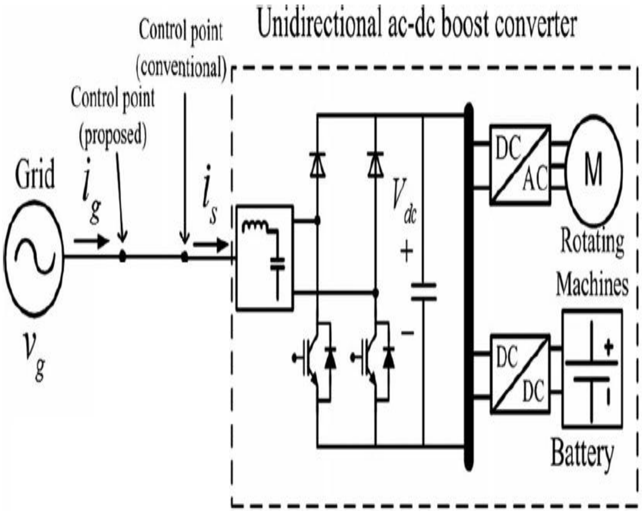

Fig.1. **Proposed system connected to linear and nonlinear loads**

This will bring about upgraded unwavering quality and execution of the pwer framework. On the other hand, V2G associations require a bidirectional force converter, which builds framework cost and intricacy contrasted with that of a unidirectional force converter.

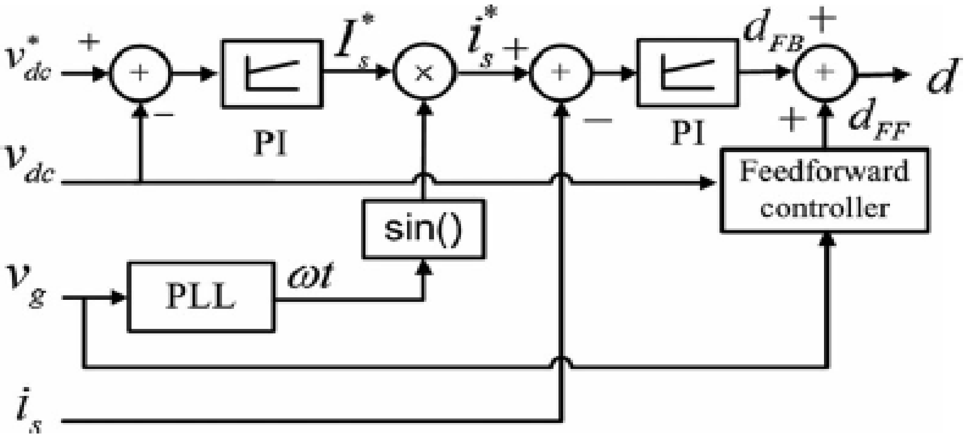

Fig.2. **CCA for Unidirectional AC-DC Boost Converter**

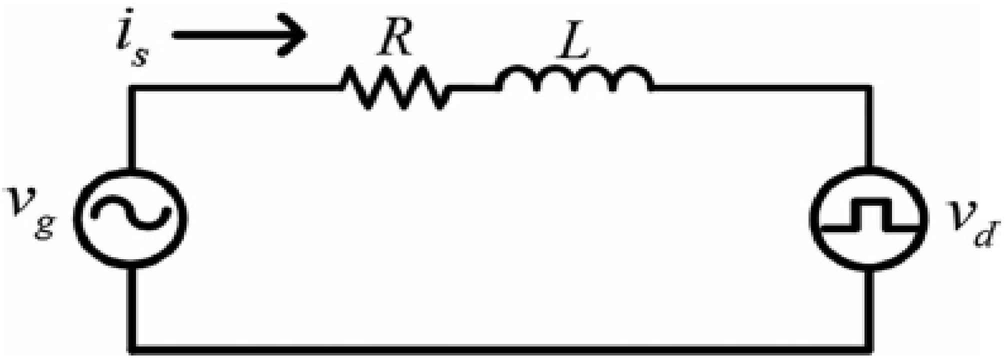

Fig.3. **Positive Half Bridge Source Voltage – Circuit View**

Therefore, a unidirectional topology is an ideal arrangement for level 1 battery chargers in EV and Plug-in Electric Vehicle [PHEV] applications, implied for private interconnections, though V2G using bidirectional converters is more appropriate for level 2 battery chargers. The motivation behind this paper is to examine a financially savvy power quality relief arrangement by using unidirectional converters, despite the fact that HCC clashes with the essential reason and preface of amplifying the force component. Since a colossal number of these unidirectional converters are available inside private force frameworks, these unidirectional converters, working as one, have a high potential as option HCC and, hence, these converters can act set up of bigger, all the more exorbitant HCC gear on the off chance that they have these functionalities.

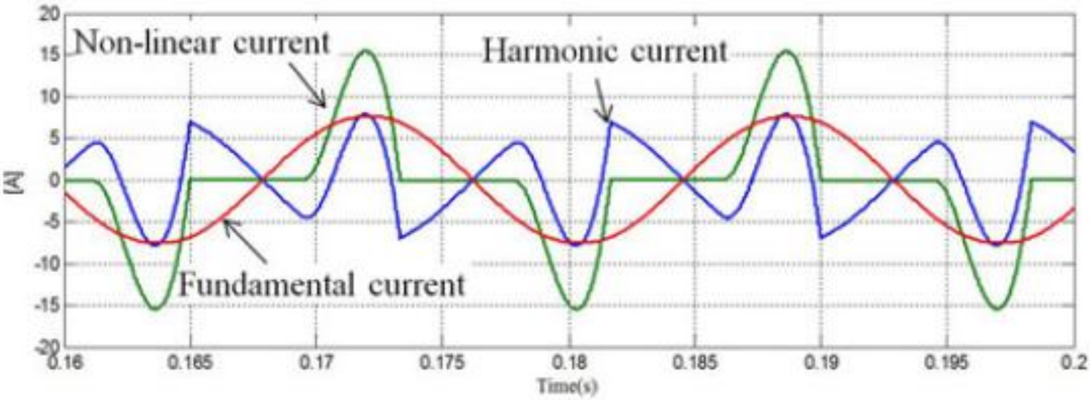

Fig.4. Instance of Non-Linear Load Current

Lately, few papers have point by point HCC functionalities utilizing unidirectional Power Factor Correction [PFC] converters. Creators extensively assessed battery charger topologies utilized for EV/PHEV applications for giving responsive force backing to the framework, however the capacity in unidirectional converters was specified quickly and any further investigation was not directed. In the plausibility of HCC usefulness utilizing a help converter was introduced as an ease arrangement, however usefulness was not specified. In the receptive force bolster capacities of the unidirectional converter inside V2G applications were contemplated through reproduction results, yet itemized investigation with respect to info current twists was not performed.

A. CONTROL MODE

The double support PFC converter, frequently called the bridgeless PFC converter, is a standout amongst the most well known unidirectional ac–dc help converters. The control calculations of the double help PFC converter are verging on indistinguishable to any traditional ac–dc converter utilizing a diode rectifier and venture up chopper, with the exception of that the double support PFC converter controls air conditioning info current, while the customary one controls corrected yield current. Fig. 1 demonstrates a predominant utilization of unidirectional ac–dc help converters. Customary PFC converters consider the information current to be an absolutely sinusoidal waveform, which is totally in stage with the data input voltage.

The proposed control strategy can enhance harmonics present and responsive force for enhanced framework power quality, and additionally regulation of dc-transport voltage. The proposed flexible control of unidirectional ac–dc support converter has three methods of operation, i.e., PFC, HCC. Likewise, HCC can work all the while to enhance the mutilation and the dislodging elements of the lattice current.

HARMONIC CURRENT COMPENSATION

Fig. 4 shows the current waveform of a typical nonlinear load in a single-phase diode rectifier. Generally, the distorted load current inon can be written in terms of its fundamental ifn and harmonic ihn components as

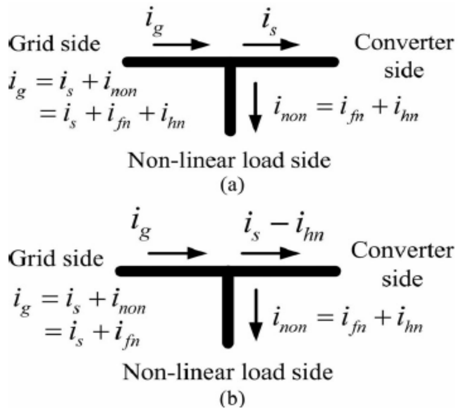

Fig.5. Harmonic Current Flow (a) without HCC (b) with HCC

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$$i_{\text{non}} = I_1 \sin(\omega_1 t + \theta_1) + \sum_{n=2,3}^{\infty} I_n \sin(n\omega_1 t + \theta_n) \qquad (4)$$

where ω1 is the line angular frequency and θn is the phase difference between the source voltage and input current. Assume that the input current from the unidirectional ac–dc boost converter operating in PFC mode is a purely sinusoidal waveform. The grid current ig includes ihn from a nonlinear load as shown in Fig. 5(a). These harmonics are undesirable and should be removed. If the unidirectional ac–dc boost converter can generate the harmonic current capable of canceling the harmonics of the nonlinear load, the grid current will be comprised of only fundamental components of the converter current and load current as shown in Fig, 5(b). Therefore, the new current reference for the current controller of the converter from Fig. 6 can be expressed as

$$i_s^* = I_s^* \sin(\omega t) - i_{\text{hn}} \qquad (5)$$

where I∗ s is the magnitude reference provided by the dc-bus voltage controller.

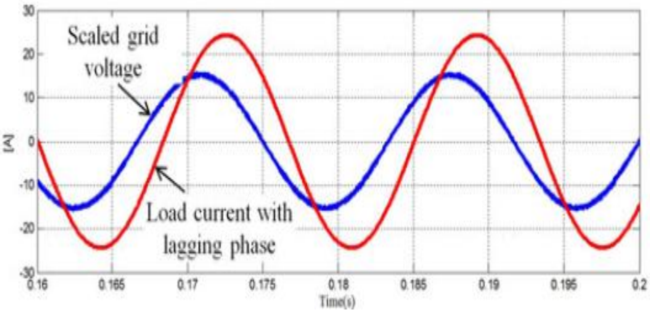

Fig.7. Instance of LLC

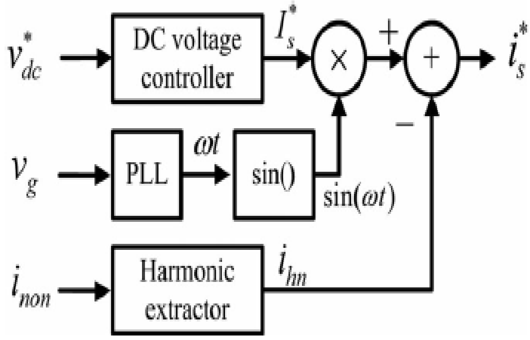

Fig.6. Current Reference Generator for HCC

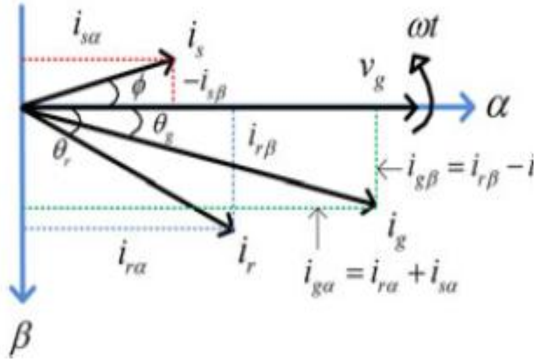

Fig 8. Phase diagram of the grid voltage and current

B. REACTIVE POWER COMPENSATION

Unlike nonlinear loads, the current waveform of a linear load is sinusoidal at the frequency of the power system [1], but the power factor can be significantly exacerbated when the load is capacitive or inductive. Fig. 7 shows the current waveform of a typical inductive load in a single-phase induction motor. The current flow, consisting of the converter current with the load current ir consuming reactive power, shown in Fig. 8, can be written, respectively, as

$$i_s = i_{s\alpha} - j i_{s\beta} \ (6)$$

$$i_r = i_{r\alpha} + j i_{r\beta} \ (7)$$

$$i_g = i_{r\alpha} + i_{s\alpha} + j(i_{r\beta} - i_{s\beta}). \ (8)$$

As a result, the grid power factor at the PCC can be improved by injecting reactive power from the converter as shown in Fig. 9. However, it should be considered that the input current of the unidirectional converter becomes distorted due to the natural commutation of diodes; thus, the amount of reactive power generated by an individual converter should be restricted [22], [29]. This will be elaborated later in this paper. Since the current waveform of the converter mode is not sinusoidal, the required phase angle of the current cannot be calculated by a simple reactive power equation. Thus, the phase angle reference to the input converter current needs to be generated by employing a proportional integral compensator as shown in Fig. 10, and can be represented as

$$\phi = K_{pc}(Q^* - Q) + K_{ic}\int (Q^* - Q)dt \qquad (9)$$

$$i_s^* = I_s^* \sin(\omega t + \phi) \qquad (10)$$

where Kpc and Kic are proportional gain and integral gain of the reactive power compensator, respectively, and φ is the desired phase to be adjusted from the original current reference. It should be noted in (10) that the current magnitude reference I∗s will be adjusted through the dc-bus voltage controller to feed active power to the dc load. The reactive power will be adjusted by changing the phase angle φ. Thus, initially I∗s is determined by the dc-link voltage controller and actual active power will change as result of generating reactive power with respect to the dc link command. However, since I∗s will be updated by the dc link voltage compensator, as the phase angle φ changes, the dc link voltage will be maintained.

C. CONTROL STRATEGY FOR APF FUNCTIONALITY

The proposed control strategy of the unidirectional ac–dc converter including a feedforward controller, HCC is shown in Fig. 11. Two control blocks for HCC have been added to the conventional control algorithm in Fig. 2. Thus, the final current reference for a versatile control strategy based on (5) and (10) can be expressed as

i∗s = I∗s sin(ωt + φ) − ihn. (11)

In addition, it is worthwhile to mention that functionalities of HCC in unidirectional ac–dc boost converters are available only when these converters supply active power to its dc load. Thus, the current reference able to be used for HCC is highly dependent on its power rating and its existing loads. Since multiple unidirectional converters may be connected to the power system in residential applications, their capabilities can be maximized by incorporating these aggregated converters as shown above. The possible supervisory control strategy for future smart grid applications can be suggested as follows:

a) Analyse grid power quality factors, such as THD and PF;
b) Calculate the amount of compensation for harmonic producing components and reactive power;
c) Obtain the available capacities used for HCC in an individual converter;
d) Determine and distribute HCC references to an individual converter;
e) Analyse the grid power quality. If the THD of the grid current is above 5%, the level of needs to be reduced, otherwise, the amount can be increased up to each converter’s maximum capacity to achieve unity power factor.
f) repeat (a) through (e).

II. RELATED WORK

In [1], "Fundamentals of Electric Power Quality. Scotts Valley", the author S. Santoso quoted on, this system introduces a versatile unidirectional ac-dc converter with harmonic current and reactive power compen-sation. Since numerous unidirectional ac-dc converters can be connected with ac power systems, existing commercial converters possess the ability to improve substantially the stability of ac power systems by compensating harmonic current and reactive power. In this paper, the feasibility and limitations of the unidirectional acdc converter are explained when it is employed for harmonic current and reactive power compensation, and a control strategy for such functionalities is proposed. A MATLAB /Simulink model and a 1 kW dual boost PFC prototype board controlled by a digital signal processor are implemented to demonstrate the effectiveness of the proposed control method for improving power quality of the grid.

In [2], "A review of active filters for power quality improvement", the authors B. Singh, K. Al-Haddad, and A. Chandra quoted on, active filtering of electric power has now become a mature technology for harmonic and reactive power compensation in two-wire (single phase), three-wire (three phase without neutral), and four-wire (three phase with neutral) AC power networks with nonlinear loads. This paper presents a comprehensive review of active filter (AF) configurations, control strategies, selection of components, other related economic and technical considerations, and their selection for specific applications. It is aimed at providing a broad perspective on the status of AF technology to researchers and application engineers dealing with power quality issues. A list of more than 200 research publications on the subject is also appended for a quick reference.

In [3], "Reactive power compensation in single-phase operation of microgrid", the author R. Majumder quoted on, a coordinated control of distributed generators (DG) and distribution static compensator (DSTATCOM) in a microgrid is proposed in this paper. With high penetration of distributed sources and single-phase operation of the system, voltage unbalance can often go beyond the acceptable limit. With the feeders geographically spread out, it is not always possible to achieve reactive compensation at optimum location with the three-phase devices. In this paper, a simple control strategy for DSTATCOM with communication in loop is proposed. The proposed reactive compensation technique is based on the voltage sag and the power flow in the line. The power flow and the voltage at different locations of the feeders are communicated to the DSTATCOM to modulate the reactive compensation. The single-phase DSTATCOM compensates for the reactive power deficiency in the phase while the DGs supply “maximum available active power.” During reactive power limit of the DG, the “maximum available active power” is fixed to a value lower than maximum active power to increase reactive power injection capability of the DGs. A primary control loop based on local measurement in the DSTATCOM always ensures a part of reactive compensation in case of communication failure. It is shown that the proposed method can always ensure to achieve acceptable voltage regulation. The data traffic analysis of the communication scheme and closed-loop simulation of power network and communication network are presented to validate the proposed method.

In [4], "Reactive power compensation technologies: State-of-the-art review" the authors J. Dixon, L. Moran, J. Rodriguez, and R. Domke quoted on, this approach presents an overview of the state of the art in reactive power compensation technologies. The principles of operation, design characteristics and application examples of Var compensators implemented with thyristors and self-commutated converters are presented. Static Var generators are used to improve voltage regulation, stability, and power factor in ac transmission and distribution systems. Examples obtained from relevant applications describing the use of reactive power compensators implemented with new static Var technologies are also described.

III.SYSTEM ANALYSIS

A. Existing Work

- Power losses due to long distance transmission of reactive power.
- Transistor connections require a bidirectional power converter ,which increases system cost and complexity.

Demerits of Existing System

- Cost expensive for long range connection establishments.
- Power losses may occur in long distance.
- Complexity is more in the implementation of using transistors.

B. PROPOSED SYSTEM

- Unidirectional AC-DC boost PFC converter, with HCC.
- Distortion levels of the current are analytically justified.
- HCC functionality using a boost converter was presented as a low-cost solution.
- Harmonic current and reactive power for improved grid power quality.
- HCC conflicts which maximizing the power factor.

Merits of Proposed System

- Cost Saving Method
- Chances of Power Losses over long transmission are less.
- Easy approach.

IV. BLOCK DIAGRAM

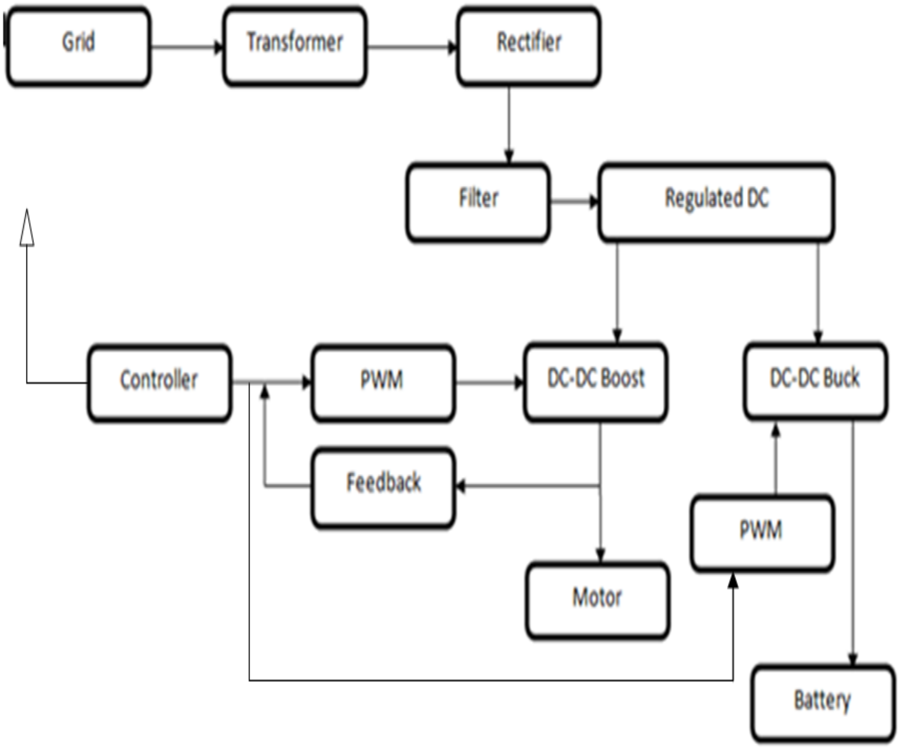

Fig.9. Block Diagram

V. CIRCUIT DIAGRAM

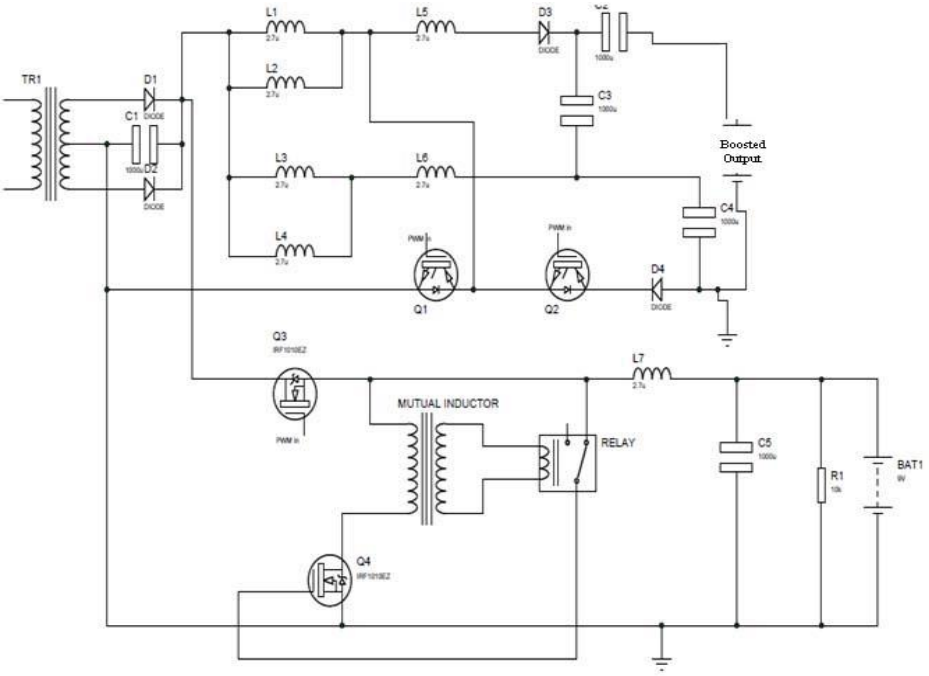

Fig.10. Circuit Diagram

VI. EXPERIMENTAL RESULTS

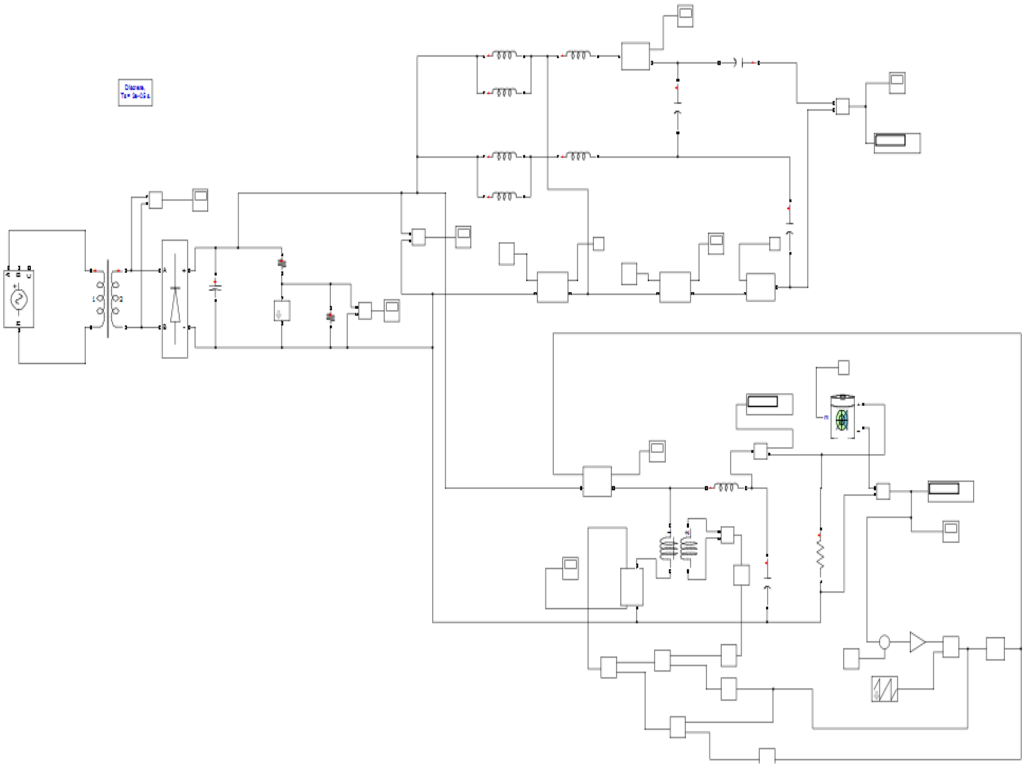

Fig.11. Overall Design

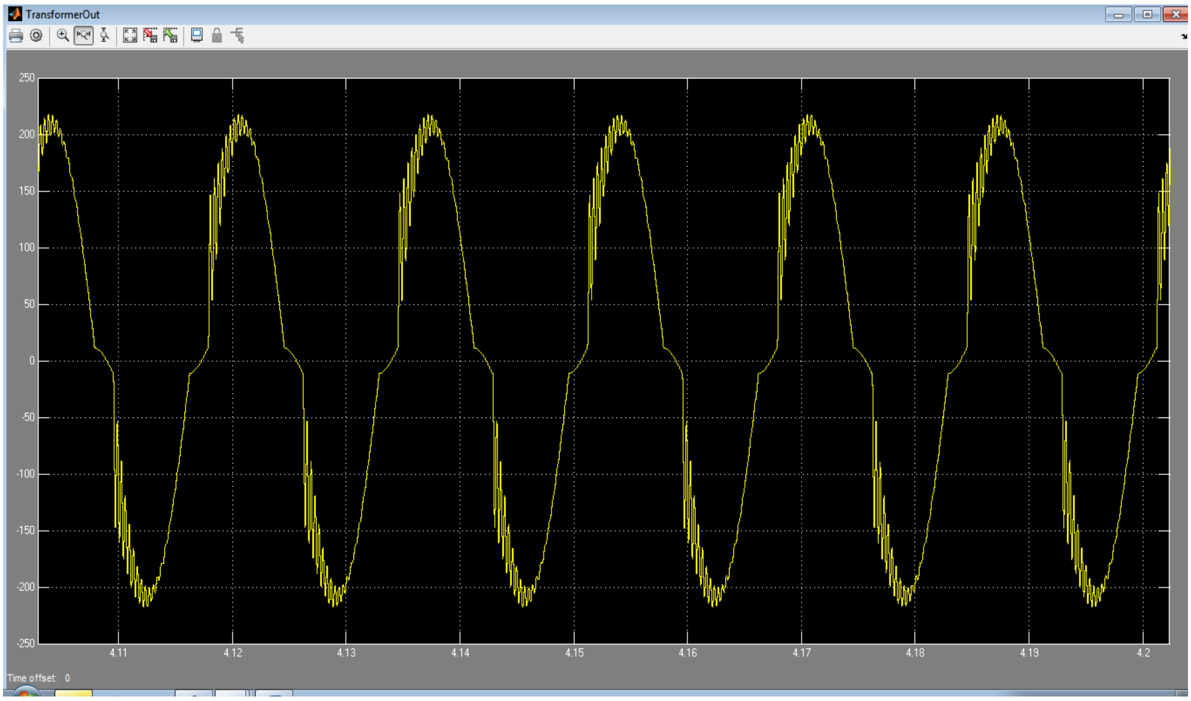

Fig.12. AC Input

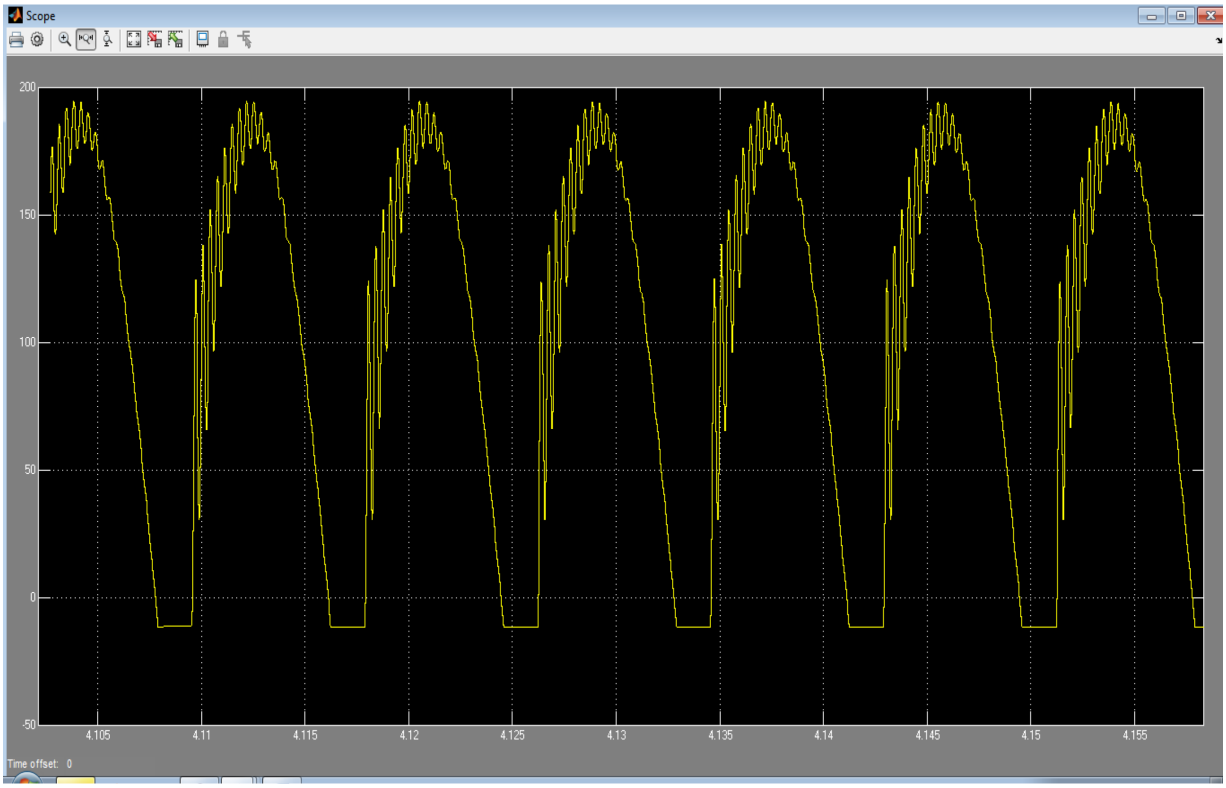

Fig.13.Full Wave Output

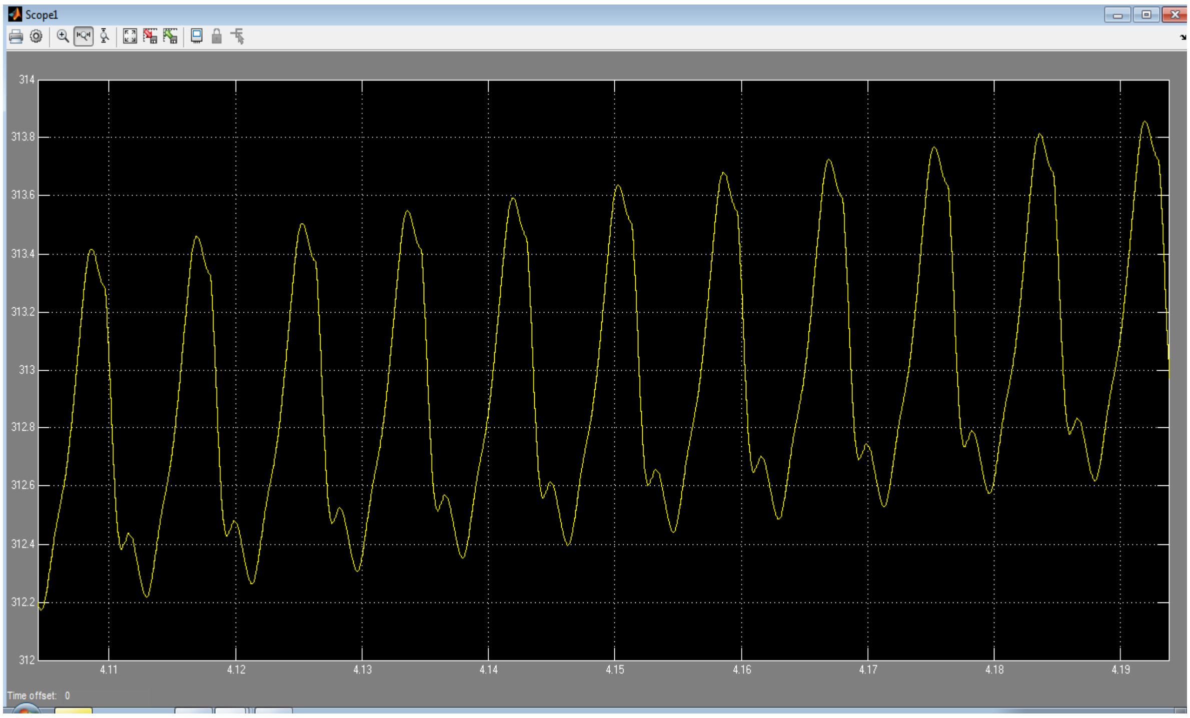

Fig.14. DC Voltage Source value is 312.2 to 313.4 almost perfect DC Voltage

VII. CONCLUSION

Since unidirectional ac–dc boost converters are already ubiquitously connected with ac power systems, existing unidirectional ac–dc boost converters possess the ability to improve substantially the stability of ac power systems by maximizing functionalities of aggregated unidirectional ac–dc boost converters. In this system, versatile control methods for the unidirectional ac–dc boost converter have been presented to enhance grid power quality through the combination of HCC, which can be a more economical solution for future smart grid applications. In addition, the framework for evaluation of the current distortion levels in unidirectional ac–dc boost converters when they are employed has been presented. The effectiveness of the proposed control method was validated through experimental results showing improved power factor and total harmonic distortion of the grid. At the same time, it should be noted that due to the inherent limitations of the unidirectional ac–dc boost converter, the grid current will be distorted unintentionally when operating mode where the THD of capacitive current is worse than that of the inductive current due to extended cusp distortions. Hence, the amount of reactive power injected from an individual converter to the grid should be restricted. Although, combined operation of these aggregated converters, each restricted, can meet the reactive power demand while still effectively compensating for generated harmonics.

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