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Hybrid Rectifier- Solution for Harmonics Problem Faced By Tamilnadu Electricity Board

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ABSTRACT*:* Power quality includes many aspects as voltage sags, voltage swell, harmonics, flicker and fluctuations. In my project proposes a new method of power quality improvement using Hybrid Rectifiers is adopted to reduce harmonics. The objective is to obtain a structure capable of providing sinusoidal input currents with low harmonic distortion and dc output regulation. Hybrid rectifiers are utilized for the flexible usage in high power and medium power applications by employing a combination of passive three phase rectifier with a parallel connection to active current shaping and injection network in order to achieve sinusoidal main current. Whenever an ac-to-dc high power conversion is performed by a diode or phase controlled rectifiers there will be a drawn of non sinusoidal current or reactive power from the source, which deteriorate the power quality. To compensate for the harmonic distortion generated hybrid rectifiers are employed. Thus the total harmonics is reduced to less than 5% by satisfying the waveform from non sinusoidal to sinusoidal in the input current with improved efficiency. The effectiveness of this proposed system was verified through MATLAB simulation and small scale prototype model**.**

KEYWORDS: Hybrid Rectifiers, Passive Rectifiers, Power Quality, Total Harmonic Distortion.

I. INTRODUCTION

Nowadays utilization of power electronics devices in the electrical loads produces about 50% of the harmonics to the system, during the conversion of AC to DC voltages. This creates distortion in the current which is drawn from the input supply. Thus a dc link current modulation system is provided for sinusoidal line current [1]. Mostly adoption of converters like buck, boost or buck-boost during the conversion for low harmonics is considered. In which fly-back converter is also implemented to achieve some benefits of reduction in inrush current with a high frequency isolation and provides a possibility for parallel operation. Can also achieve a power factor about 0.95. Along with buck or boost converter PWM rectifier is utilized. In these type of combinations, there will be two loops in which one for managing the output voltage by controlling the dc link current as per the reference value in the outer loop and another loop present inside will gives signals for buck and boost operations at the output stage. This gives the sinusoidal current and suitable for continuous conduction mode (CCM). Sometimes functioning in discontinuous conduction is essential which produces low output can be resolved by DC link current inductor by adding an offset. Fly back converter provides both shaping and control of mean value [2][3][4]. Various rectifiers are used for the heavily unbalanced mains voltage conditions. During the unbalanced grid voltage there will be lots of harmonics in AC current and DC voltage which also reduces the power factor, even it may damage the rectifiers in the system. In direct power control of PWM rectifier, high sampling frequencies are provided and elimination of twice grid frequency oscillation in both active and reactive power is obtained. Also in the operation of PWM current source rectifier LC filters are used for mitigation of line current harmonics. A proposal of resistive damper and three step control signal compensator is used for reduction LC resonance without affecting fundamental power flow. Through this transient performance also improved. For telecommunication power supplies in heavily unbalanced main voltage condition delta rectifiers with two stages are adopted in which input side provided with parallel connected DC output. Controlling of input current will control the output by giving some features like load sharing and main voltage controlling that is earth fault, missing phase problems or other problems. From this delta rectifier the output can be improved by earlier determination which not achieved in direct three phase rectifier due to the input conductance value[5][6][7][8]. Power factor is also altered due to the harmonics which is correlated by programmable power factor correction rectifiers. It induces input current

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spectrum with auxiliary functions with phase angle of 60 degree. It is mainly for 3rd harmonics [9]. Three phase shunt rectifiers are used for harmonic compensation in which perturbations are compensated in main current that is deviations are rectified. Reference current is regulated by Average Current Mode Control (ACMC). And also utilized PQ algorithms for maintaining the sinusoidal current [10]. Three phase rectifiers with series connected dual boost converter are also used for shaping the input current. It provides low switching losses and low current ratings. In this current injection is done by a single phase and other two phases will provide low THD. If single switch is utilized then the cost can be lowered [11][12]. At the distributed generation sensor fewer operations are also performed by using PWM rectifier. In which PWM is directly connected to the generator terminals without AC reactors. Generator EMF itself enough for synchronous angle development. This estimation helps to measure the AC line current by achieving unity power factor[13]. Multiphase AC to DC converters are also used for reduction of harmonics by minimizing the ripples [14] .

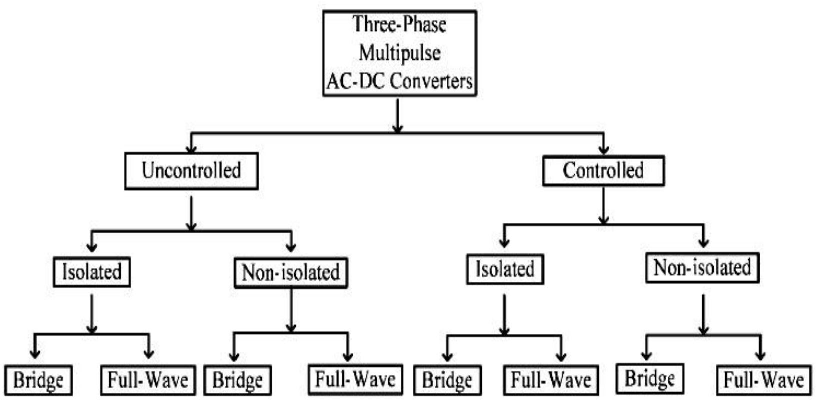
Thus various literatures helps to proposes the new hybrid rectifier employs a three phase diode bridge rectifier and a three phase PWM rectifier connected in parallel by compensating all the features and achieving a low harmonics by producing sinusoidal current. And also high power factor is achieved with improved efficiency.

II. THREE PHASE RECTIFIERS

Single phase rectifiers, extensively used in low power applications. They are also found useful for supplying small dc loads rarely exceeding 5 KW. Above this power level three phase ac-dc power supplies are usually employed. Single phase ac – dc converters have several disadvantages such as

- Large output voltage and current form factor.
- Large low frequency harmonic ripple current causing harmonic power loss and reduced efficiency.
- Very large filter capacitor for obtaining smooth output dc voltage.
- Low frequency harmonic current is injected in the input ac line which is difficult to filter. The situation becomes worse with capacitive loads.

Many of these disadvantages are mitigated to a large extent by using three phase ac – dc converters. In a way it is also natural that bulk electrical power is always transmitted and distributed in three phases and high power should load three phases symmetrically. Poly phase rectifiers produce less ripple output voltage and current compared to single phase rectifiers. The efficiency of poly phase rectifier is also higher while the associated equipments are smaller. A three phase supply gives the choice of a number of circuits. These can be placed in one of two groups according to whether three or six diodes used. These topologies will be discussed in detail in this section.



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Multi pulse converters (MPCs) can be classified based on power flow, number of pulses, and the isolated and non isolated topologies. Classification of MPCs is shown above. These converters are developed in such vast varying configurations to full fill the exact requirements of a wide range of applications. In this paper, 3 phase full bridge uncontrolled diode converter of non-isolated type and a 3 phase unidirectional PWM rectifier are used so we will discuss that type only.

Three phase half wave converter suffers from several disadvantages. Chief among them are dc component in the input ac current, requirement of neutral connection and comparatively lower output voltage. In addition the input and output waveforms contain lower order harmonics which require heavy filtering. Most of these disadvantages can be mitigated by using a three phase full wave bridge rectifier.

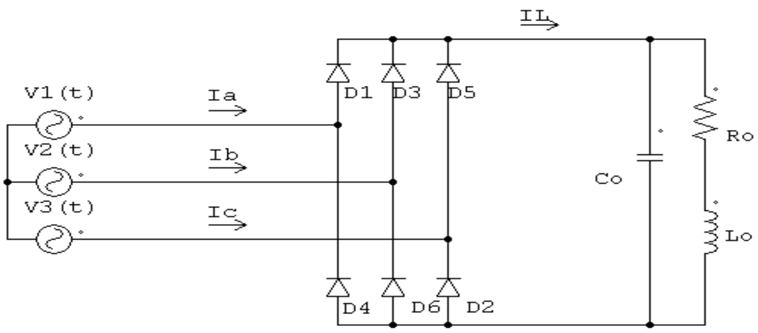

Fig 1 Three phase full wave uncontrolled bridge rectifier

Device/mode	V_{D1}	V_{D2}	V_{D3}	V_{D4}	V_{D5}	V_{D6}	V_0
D_1D_2	0	0	V_{ba}	V_{ca}	V_{ca}	V_{cb}	V_{ac}
D_2D_3	V_{ab}	0	0	V_{ca}	V_{cb}	V_{cb}	V_{bc}
D_3D_4	V_{ab}	V_{ac}	0	0	V_{cb}	V_{ab}	V_{ba}
D_4D_5	V_{ac}	V_{ac}	V_{bc}	0	0	V_{ab}	V_{ca}
D_5D_6	V_{ac}	V_{bc}	V_{bc}	V_{ba}	0	0	V_{cb}
D_6D_1	0	V_{bc}	V_{ba}	V_{ba}	V_{ca}	0	V_{ab}

Table.1 Diode Conduction Table

The load current is assumed to be continuous at least one diode from the top group (D_1, D_3 and D_5) and one diode from the bottom group (D_2, D_4 and D_6) must conduct at all time. It can be easily verified that only one diode from each group (either top or bottom) conducts at a time and two diodes from the same phase leg never conducts simultaneously. Thus the converter has six different diode conduction modes. These are D_1D_2, D_2D_3, D_3D_4, D_4D_5, D_5D_6 and D_6D_1. Each conduction mode lasts for $\pi/3$ rad and each diode conducts for 120°.

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For example the D_1 D_2 conduction mode will occur when the voltage across all other diodes (i.e. v_{ba}, v_{ca} and v_{cb}) are negative. This way the sequence of conduction modes become,

$$D_1 D_2 \rightarrow D_2 D_3 \rightarrow D_3 D_4 \rightarrow D_4 D_5 \rightarrow D_5 D_6 \rightarrow D_6 D_1 \rightarrow D_1 D_2 \text{ ---.}$$

The conduction Table-1 is constructed accordingly.

III. PROPOSED HYBRID RECTIFIER

The proposed hybrid three-phase rectifier is originated by the parallel connection of a three-phase diode bridge rectifier and a bidirectional Boost-type three-phase PWM rectifier. A diagram of the circuit generation of the proposed hybrid rectifier is presented in Fig.2. However, it is not possible to connect the both rectifiers directly due to the step up characteristic of the Boost-type PWM rectifier. Thereby, the hybrid configuration should employ a circuitry to connect the both rectifiers. This circuit can be connected in the AC-side or in the DC-side of the hybrid rectifier. The AC-side connection is performed by means of a three phase transformer (or autotransformer.) . The DC-side connection can be performed by means of a ZVT-ZCT based DC-DC boost converter.

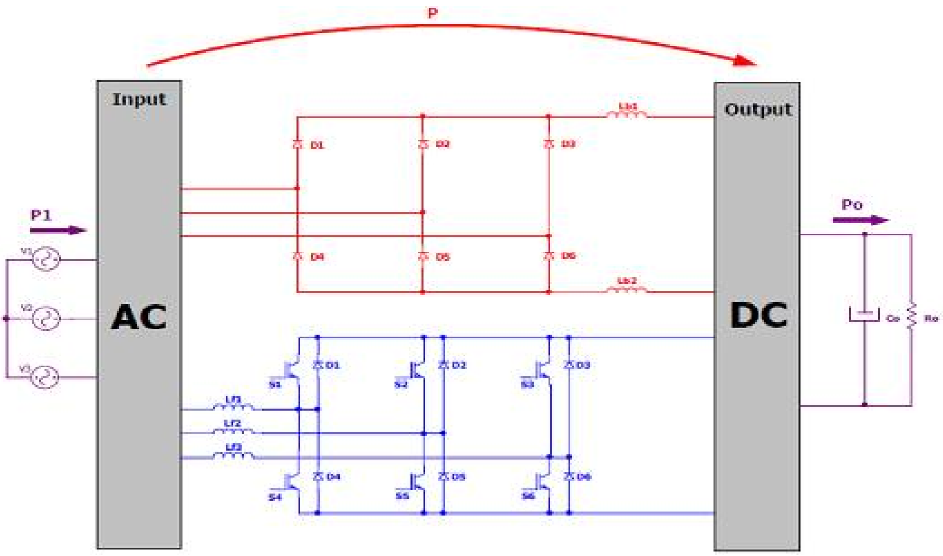

Fig 2 Circuit generation of the Proposed Hybrid Rectifier

The parallel connection of a three-phase diode bridge rectifier and a unidirectional three-phase PWM rectifier is the basis for the proposed hybrid converter. The total output power of the hybrid converter is processed largely by the uncontrolled rectifier operating at low frequency while the PWM controlled rectifier, operating at high frequency, only processes about 45% of the power. By doing so, the overall efficiency of the system will increase.

Four current control loops and one voltage control loop are used. The dc output voltage regulation is provided by the voltage control loop. The signal obtained at the output of voltage controller is used to adjust the currents' references in case the load or input voltage changes. The inductor current of the single-switch boost rectifier is sampled and compared to a constant reference. The error produced by this comparison is applied to the boost current compensator, and the PWM modulator generates the gate signal of the boost switch. Currents $ia_1(t)$, $ia_2(t)$, and $ia_3(t)$ are indirectly controlled by sensing the mains currents and comparing them with their respective sinusoidal references. A good practical solution to obtain these signals is through synchronization transformers connected to the mains to obtain the voltage shape of each phase. The errors produced by the comparisons between the sampled signals and reference

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signals are applied to their respective compensators, and the PWM modulators generate the gate signals of the active rectifier.

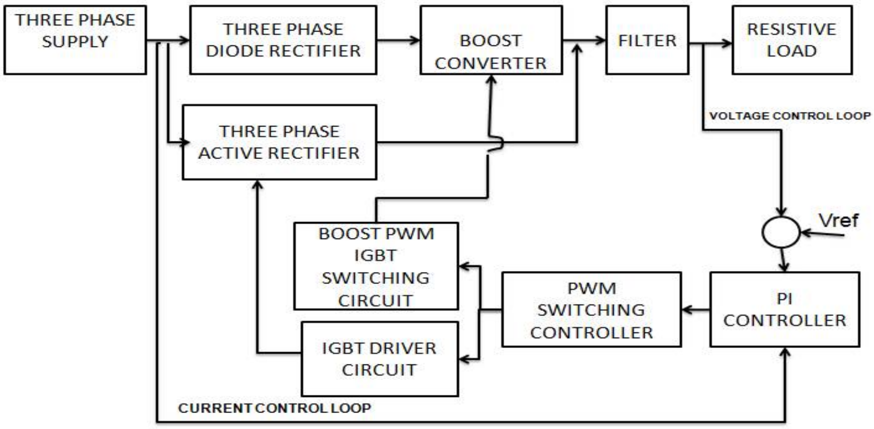

Fig 3 Functional Block Diagram

IV. SIMULATION ANALYSIS

To verify the performance of the proposed control strategy, a MATLAB-SIMULINK modal of the Hybrid rectifier is developed. To illustrate the design feasibility of the proposed converter, the following specifications is chosen

Description	Value
True Power	1 Kw
Power Factor	Almost Unity
Efficiency	> 94%
Input AC Voltage	220 V
Maximum Output DC Voltage	700V
Voltage THD	0.009%
Current THD of Passive Rectifier	31.1 %
Current THD of Hybrid Rectifier	11 %

Table 2. Simulation Results

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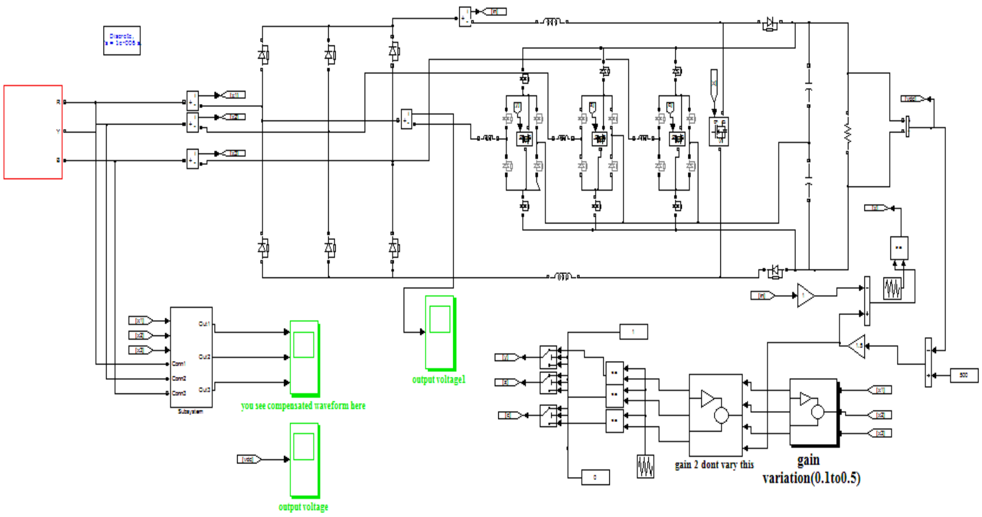

FIG. 4 Simulation Diagram of Proposed Hybrid Rectifier

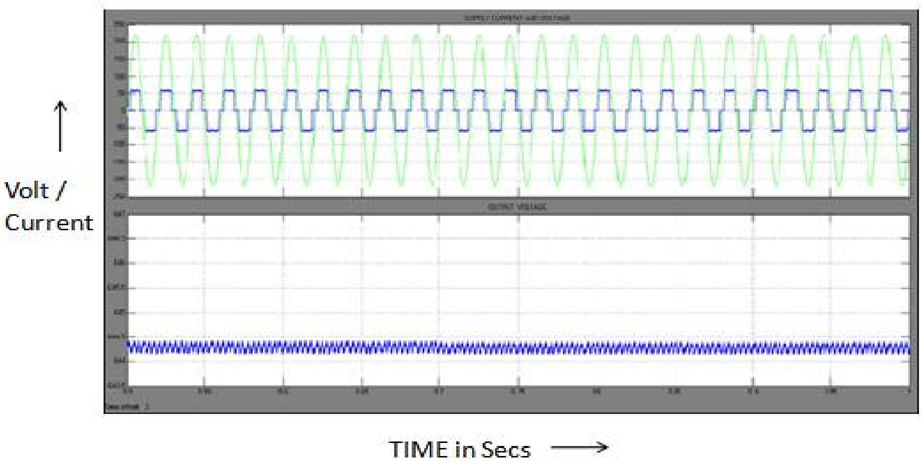

Fig: 5 Source voltage, source current and output voltage waveforms of hybrid rectifier without active rectifier

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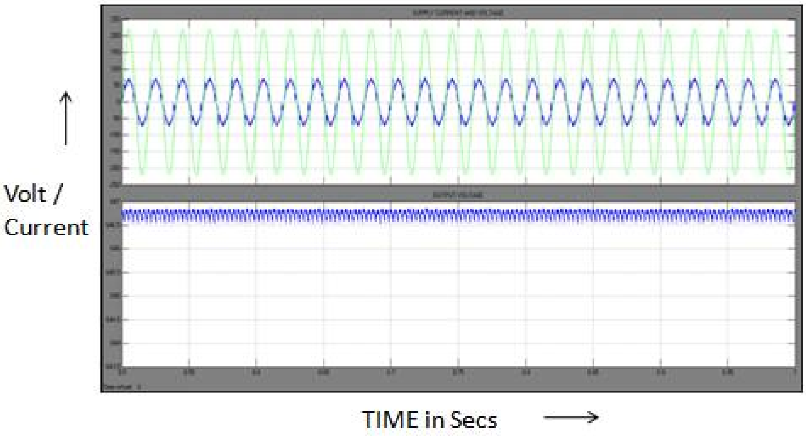

Fig: 6 Source voltage, source current and output voltage waveforms of hybrid rectifier with active rectifier.

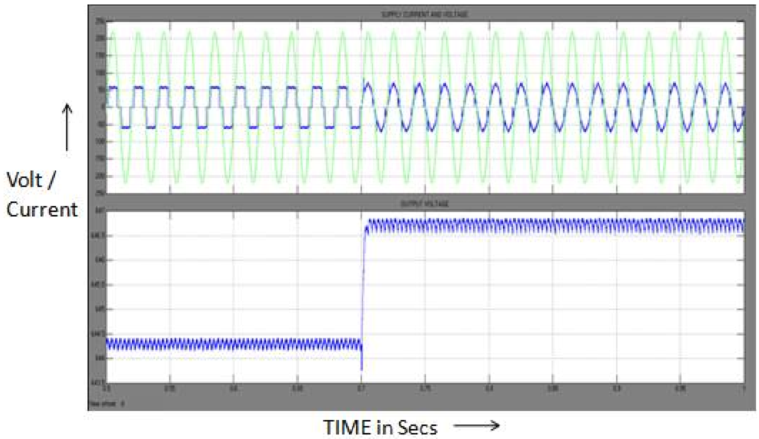

Fig 7 Source voltage, source current and output voltage waveforms of hybrid rectifier.

In order to obtain the difference clearly here up the time of 0.7t active rectifier is made to be inactive. The difference in performance of the hybrid rectifier is obtained that is up to 0.7t the converter draws square wave current from source due to absence of active rectifier after 0.7t the converter draws current is sine wave.

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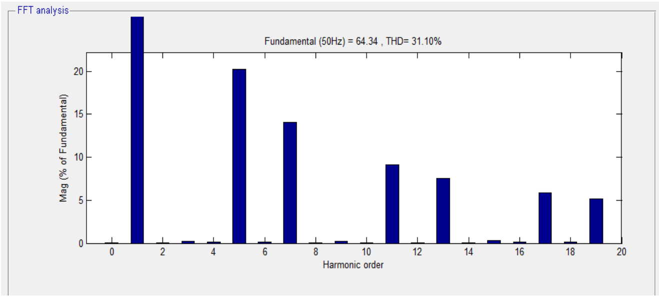


Fig 8. FFT Analysis Source Current (Passive Rectifier Alone)

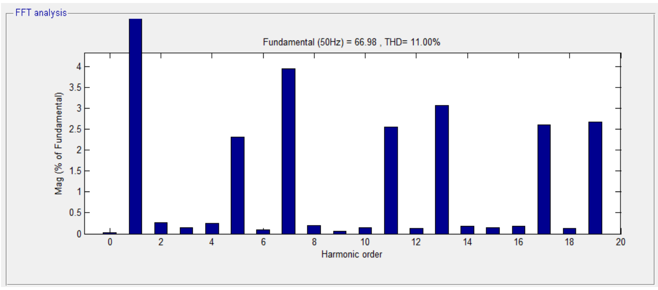


Fig 9.FFT Analysis of Hybrid Rectifier

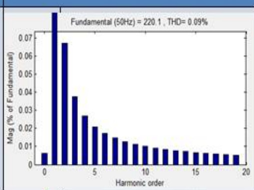
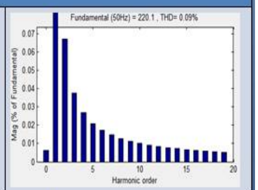
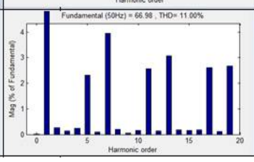
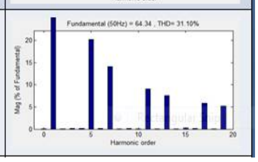
DESCRIPTION	WITH ACTIVE RECTIFIER	WITH OUT ACTIVE RECTIFIER	
V-THD 0.09%		V-THD 0.09%	
I-THD 11%		I-THD 31.1%	

Fig 10. Comparative study of source voltage and current based on THD

V. HARDWARE IMPLEMENTATION

Power supply is an integral parts a vital role in every electronic system and hence their design constitutes a major part in every application. In order to overcome mal operation which results due to fluctuations in the load and discontinuity in the supply proper choice of power supply is indeed a great need in thus hour.

The present chapter introduces the operation of power supply circuits built using filters, rectifiers, and then voltage regulators. Starting with an AC voltage, a steady DC voltage is obtained by rectifying the AC voltage, then filtering to a DC level, and finally, regulating to obtain a desired fixed DC voltage. The regulation is usually obtained

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from an IC voltage regulator unit, which takes a DC voltage and provides a somewhat lower DC voltage, which remains the same even if the input DC voltage varies, or the output load connected to the DC voltage changes.

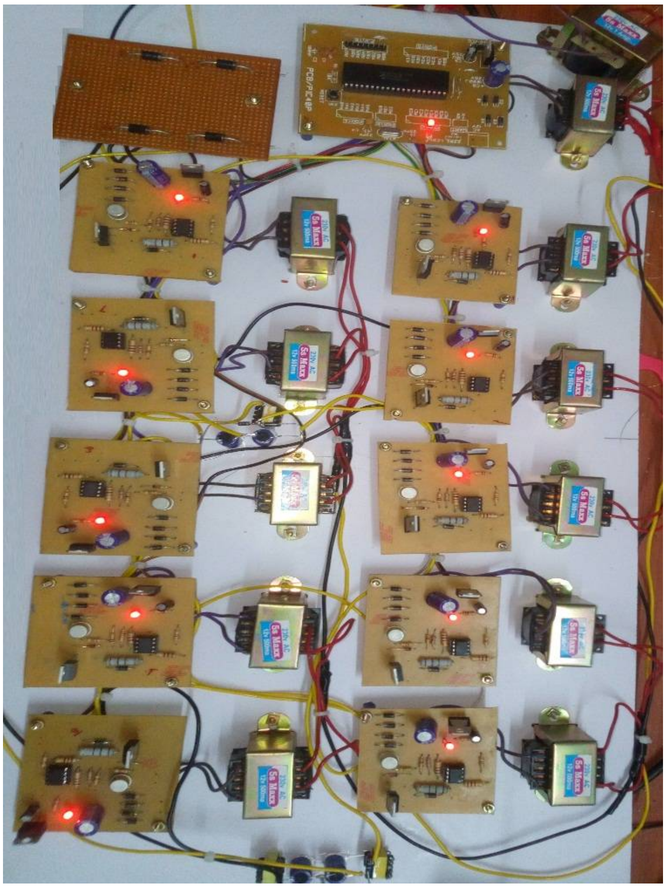

Fig 11 Photocopy of Proposed Hardware

Output current wave forms

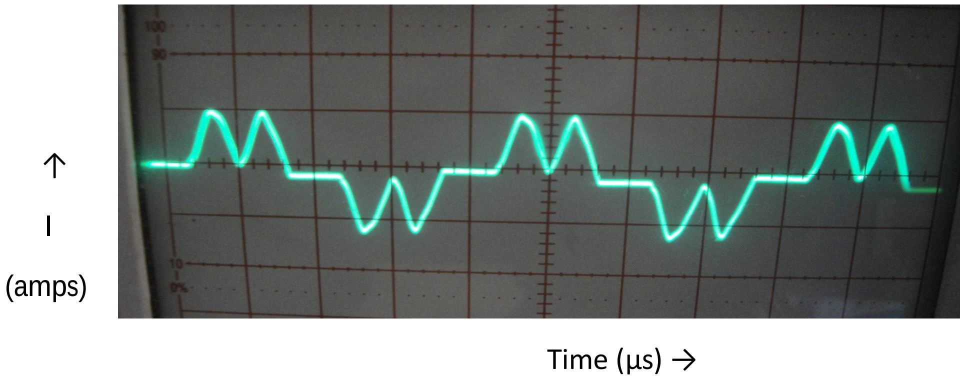

Fig 12 Hardware Output of Current drawn by Passive Rectifier

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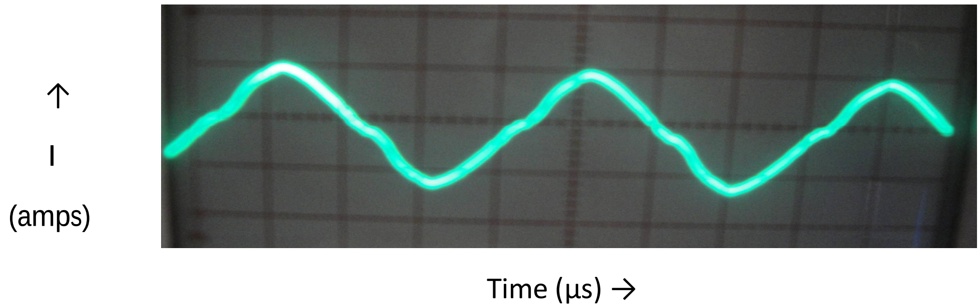

Fig 13 Hardware Output of Current drawn by Hybrid Rectifier

VI. CONCLUSION

Proposed Hybrid rectifier is capable of delivering high power levels due to parallel association of rectifiers.The increase of component count does not affect strongly the volume of the rectifier because the components are designed for half of the output current rates.The current THD values meets IEEE and IEC standards. This converter presents high power factor and DC voltage regulation. Increased efficiency is the advantage. Proposed Hybrid rectifier was subsequently implemented in hardware for a positive confirmation.

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