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A simplified PWM technique for PV fed Five-Level Five switch Multilevel Inverter

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A B S T R A C T

Bulk electrical power generation is generated using fossil fuels which emit huge pollution which is a global constraint today. Nonconventional sources of energy are the alternative energy sources for power generation. Non-conventional sources like PV (photovoltaic) system are used as power source now-a-days. Multi-level inverters (MLI) are dominating inverter circuits giving out voltage with less distortion eventually reducing voltage stress on switches and size of filter. This paper presents a MLI structure with five switches giving out five-level output from the inverter. PV system is used as source and boost converter amplifies the PV output voltage to desired value. The paper presents a simplified PWM (pulse width modulation) technique for PV fed five switch five-level inverter. The proposed system is developed and results are obtained using MATLAB/SIMULINK software. Results are presented for the system con sidering R-load and RL-load conditions.

Keywords:PWM; multilevel inverter; reduced switch

1. Introduction

Fossil fuels can generate electrical power in bulk but emission of greenhouse gases is the global issue these days with using conventional fossil fuels. To reduce the carbon gases emission from conventional power plants, renewable energy sources is the best alternative to provide stability to power system reducing the power generation from conventional plants. Photo-voltaic (PV) system [3-4], wind system, fuel-cells are examples used in renewable sources for power generation. PV system is one of the forefront generation scheme employed in major. PV cell is a simple P-N junction layer to produce potential barrier between the two layers. Photon from the light energy when absorbed by the charge carriers in PV cell, electrons starts flowing and giving rise to current flow [5-6].

PV generates DC kind of source and requires an inverter to feed load. General two-level inverters suffer from high distortion in output voltage. Two-level inverter impresses high stress on switching devices. This disadvantages leads to development of multi-level inverters [7-10]. As the level of output from inverter is increased, harmonic distortion is reduced and also the stress across switch reduces reducing the switching losses.

This paper presents a MLI structure with five switches giving out five-level output from the inverter. PV system is used as source and boost converter amplifies the PV output voltage to desired value. Figure 1 illustrates the block representation of proposed concept PV fed MLI. The paper presents a simplified PWM (pulse width modulation) technique for PV fed five switch five-level inverter. The proposed system is developed and results are obtained using MATLAB/SIMULINK software. Results are presented for the system considering R-load and RL-load conditions.

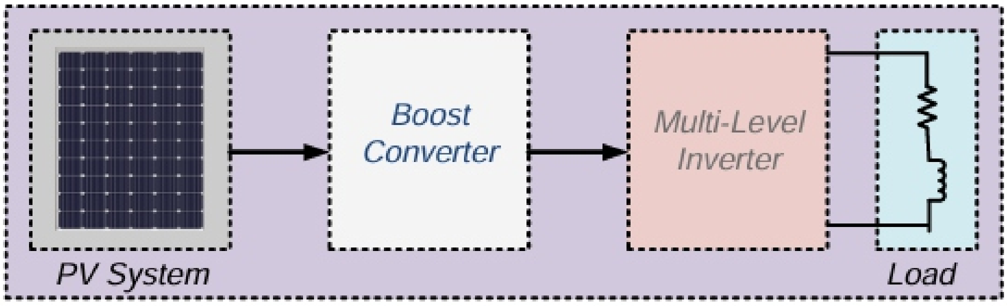


Fig. 1: Block representation of PV fed MLI

2. PV Fed Multi-Level Inverter

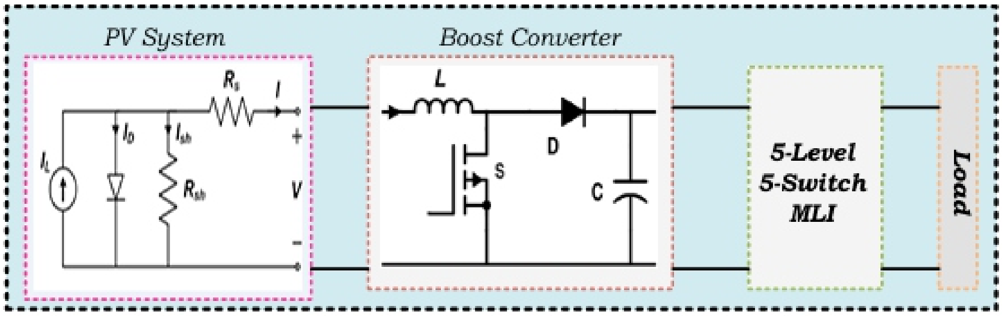


Fig. 2: PV system (with boost converter) fed MLI

Figure 2 illustrates the PV system (with boost converter) fed MLI. Solar energy when irradiated on solar panel, the PN layers in solar panels absorb the photon energy from solar energy and current flows breaking the barrier between PN junctions allowing voltage to present across PV output. The PV system generally produces low voltage DC output which needs additional converter to stepup the voltage level. Boost converter steps up the voltage level of PV output to required level. Conventional boost converter consists of passive components like L, C for boost operation and the charging and discharging are controlled using a controlled switch. The output of boost converter is fed to multi-level inverter which produces multiple leveled outputs reducing the inverter output voltage and current distortion.

A. Design of Boost Converter

Input voltage (V_{in}) = 100V,V_O = 400V

Output power (P_O)=20 kW, F=20kHz

O/P current $I_O=\frac{P}{V_O}=\frac{20\times10^3}{400}$= 50Amps

O/P resistance $R=\frac{V_O}{I_O}=\frac{400}{50}=8\Omega$

$\frac{V_O}{V_{in}}=\frac{1}{1-D}$

$\frac{400}{100}=\frac{1}{1-D}$

1-D = 0.25

D = 1-0.2 5= 0.75

∴ Duty ratio D = 0.75

$V_O I_O=V_{in} I_{in}$

$I_{in}=\frac{400\times50}{100}$

I_{in}= 200 Amps
Ripple current ΔI = 5% of I_{in}
$\Delta I = \frac{5}{100} \times 200 = 10$ Amps
Ripple voltage ΔV_C = 5% of Output voltage
$\Delta V_C = \frac{5}{100} \times 400 = 20$ volts
We have
$\Delta I = \frac{V_{in \times D}}{f \times L}$
$L = \frac{V_{in} \times D}{f \times \Delta I}$
$L = \frac{100 \times 0.75}{20 \times 10^3 \times 10}$
$L = 0.375 \times 10^{-3} H$
$\therefore L = 0.375 mH$
Let $I_0 = I_C = \frac{V_O}{R} = \frac{C_d \Delta V_C}{dt}$
$C = \frac{V_O \times D}{R \times \Delta V_C \times f} = \frac{400 \times 0.75}{8 \times 20 \times 20 \times 10^3}$
$\therefore C = 93.7 \mu F$

3. PV fed Five Switch Five-Level Inverter

Figure 3 shows the five-level multilevel inverter with five switches. In this case the circuit consists of two voltage sources of same magnitude. Four IGBT switches (S1 to S4) are used and one bidirectional switch (S5) is used at source side.

A. Five switch Five-level inverter topology

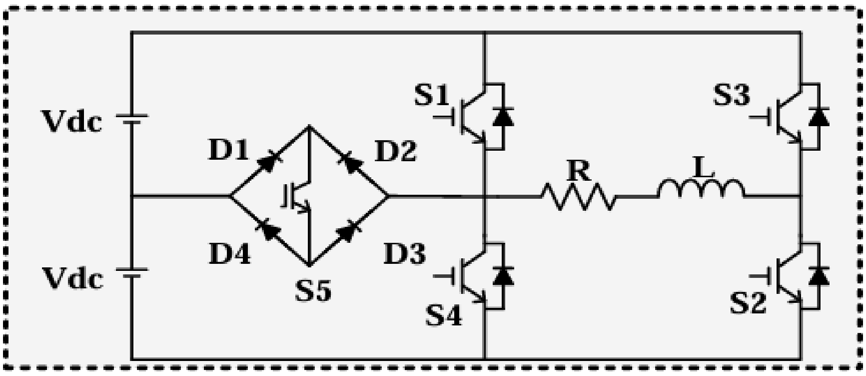


Fig. 3: 5-level multilevel inverter with five switches

Table 1: Switching pattern

Voltage levels	Switching Sequence				
	S_1	S_2	S_3	S_4	S_5
$2V_{dc}$	1	1	0	0	0
V_{dc}	0	1	0	0	1
0	0	1	0	1	0
$-V_{dc}$	0	0	1	0	1
$-2V_{dc}$	0	0	1	1	0

Table 1 gives the switching sequence for 5-level multilevel inverter with five switches. From the table it is clearly understood that which switches are operating for a particular output voltage level. '0' indicates the switch OFF condition and '1' indicates the switch ON condition.

B. PV Fed five switch five-level inverter

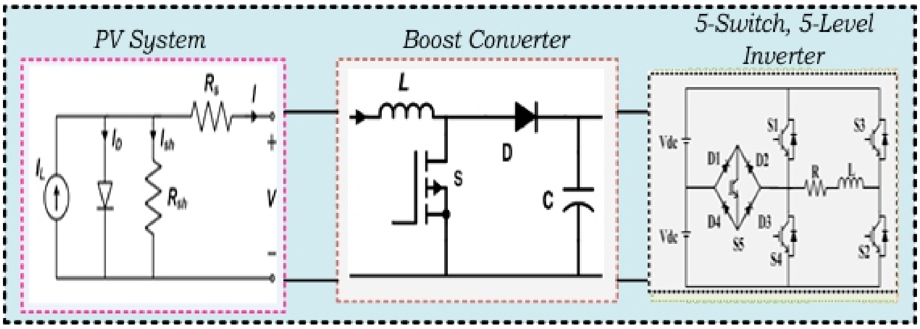


Fig. 4: PV fed five-switch five-level inverter

Figure 4 illustrates PV fed five-switch five-level inverter. The input to the topology of five-switch five-level inverter is boost output. PV output is boosted using boost converter and the output of boost converter is fed to five-level five switch inverter. terminal voltage across load gives five-level alternating output voltage. Boost converter is operated n closed-loop mode. The output capacitance voltage of boost converter is split across two capacitors of inverter. Two capacitors share the voltage and generate five-level output voltage across load by sequential switching as give in table-1.

C. Control logic for five switch five-level inverter

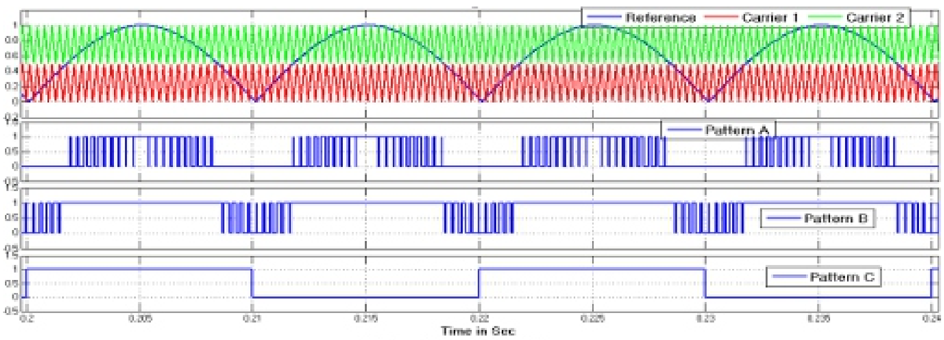


Fig. 5: PWM pattern

Several modulation strategies are used in multi-level inverters for several applications to control the output voltage waveform. Generally, PWM strategies are comprised into three objectives, such as fundamental switching frequency PWM technique, carrier based PWM technique, space vector PWM technique. Out of all, the multi-carrier based PWM techniques are more popular because of low complex function when the more number of output voltage levels. This paper employs the new multi-carrier based pulse width-modulation (PWM) technique consisted of one reference signal (Vref) were compared with a dual carrier signals (Vcar1, Vcar2). All the carriers had high switching frequency with a little difference in peak magnitude which is vertically disposed. The carrier signals are compared with dual carrier signals to generate the switching states A and B.

These switching states A and B are controlled by additional pulse generated switching state C. The generation of optimal pulses to the proper switches is defined by mathematical notation which is depicted in Eqn. (1). The PWM pattern of producing states of the proposed 5-level five-switch MLI is depicted in Fig.5.

$S1 = A \cdot C$
$S2 = (\bar{B} \cdot \bar{C}) + C$
$S3 = B \cdot \bar{C}$
$S4 = (A \cdot \bar{C}) + (\bar{B} \cdot \bar{C}) + (\bar{B} \cdot C)$
$S5 = \bar{A} \cdot B$

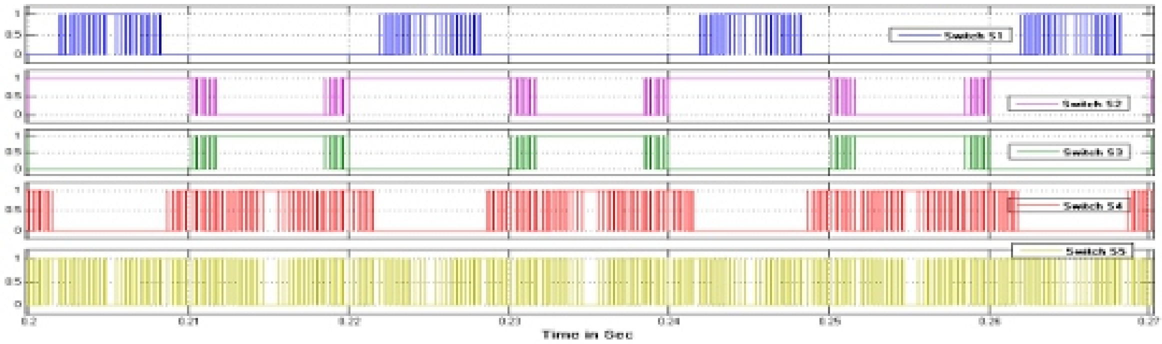


Fig. 6: Switching pattern

Pattern A, B, C operated logically as in (1) produces switching pulses as shown in figure 6 respective switches of five-level fiveswitch inverter.

The digital logic for producing pulses to five switches in proposed five-level inverter is shown in (1). The overall system with PV fed five-level five-switch inverter with control logic is shown in figure 7.

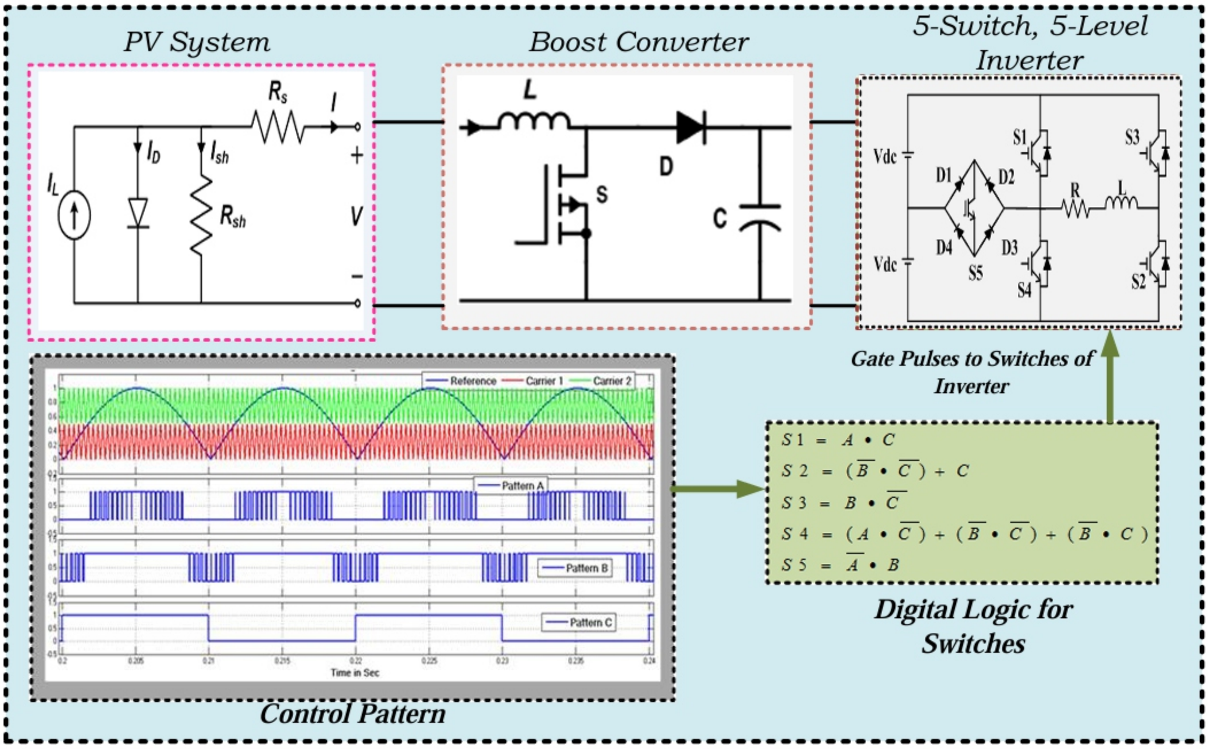


Fig. 7: Overall system with control logic

4. Result Analysis

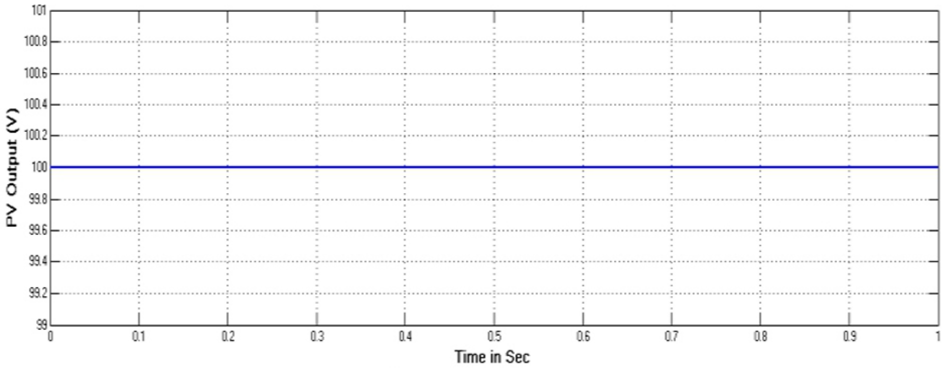


Fig. 8: PV Output

Figure 8 illustrates output voltage of PV system. PV system gives out 100V constant output voltage. The solar output remains constant over a period of time.

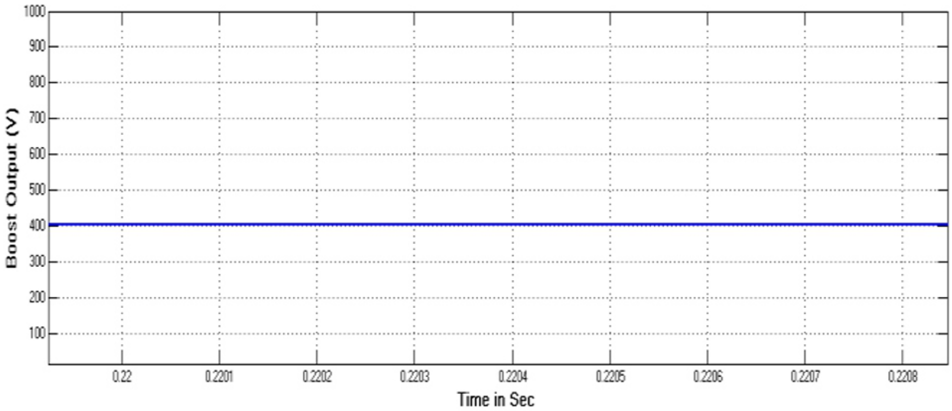


Fig. 9: Boost Output voltage

Figure 9 shows the output voltage of boost DC-DC converter. Output voltage of PV system is 100V and the 100V is fed as input to boost converter. The boost converter steps up the level of voltage to 400V at the converter output as shown in figure.

A. R-Load Condition

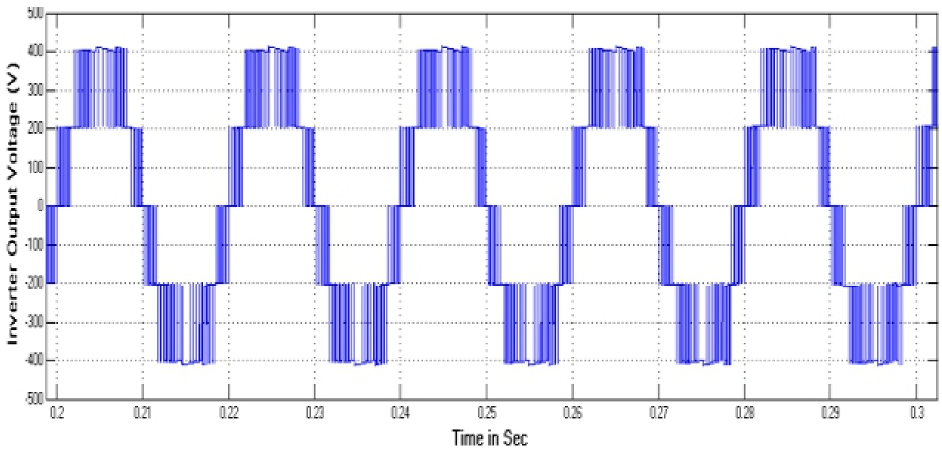


Fig. 10: Inverter Output Voltage

Figure 10 shows the output voltage of five-switch five-level inverter. The output voltage consists of five levels with peak 400V.

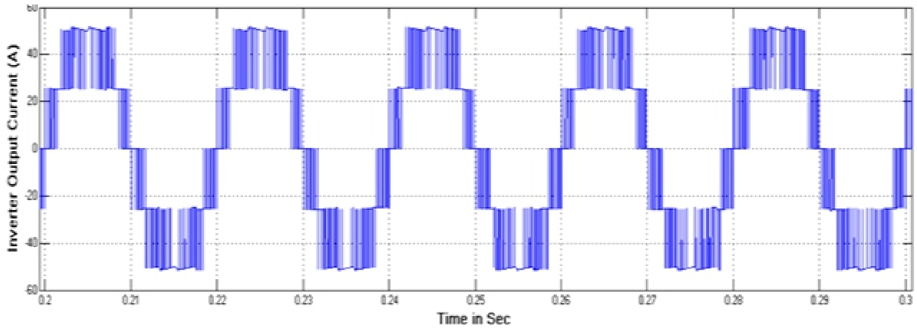


Fig. 11: Inverter Output Current

Figure 11 shows the output current of five-switch five-level inverter. The output current consists of five levels with peak 50A.

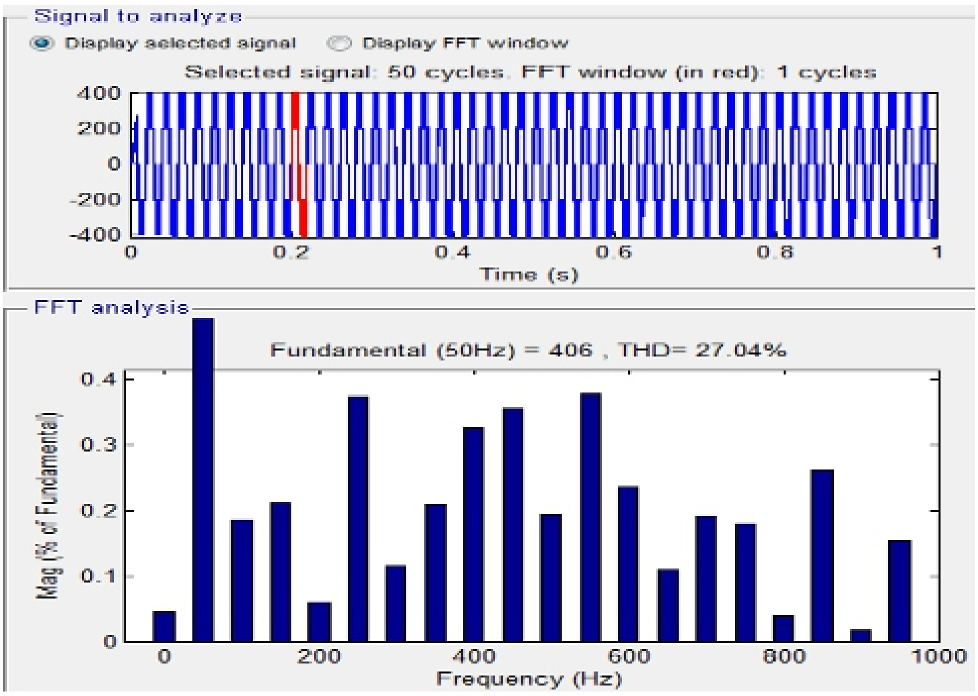


Fig. 12: THD in Voltage

Figure 12 illustrates the FFT window of harmonic distortion in inverter output voltage. Inverter output is five leveled output consisting of 27.04% distortion with respect to fundamental component.

B. RL-Load Condition

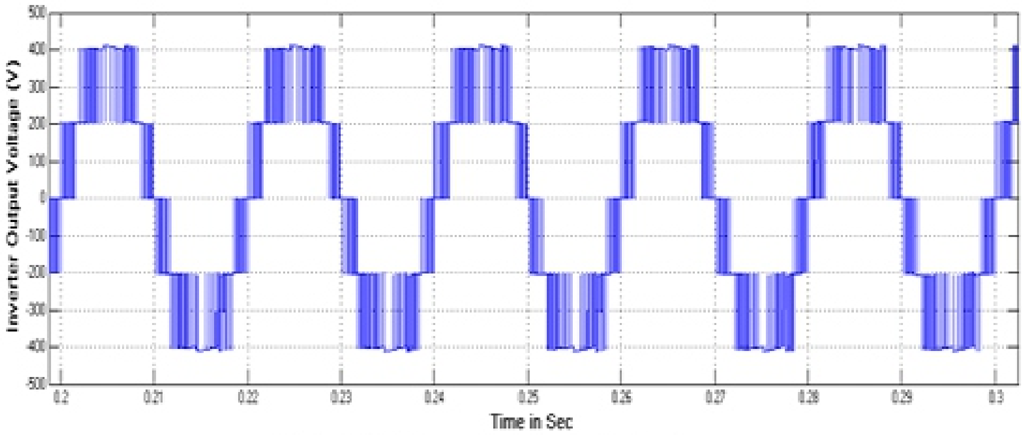


Fig. 14: Inverter Output Voltage

Figure 14 shows the output voltage of five-switch five-level inverter. The output voltage consists of five levels with peak 400V with RL-load condition.

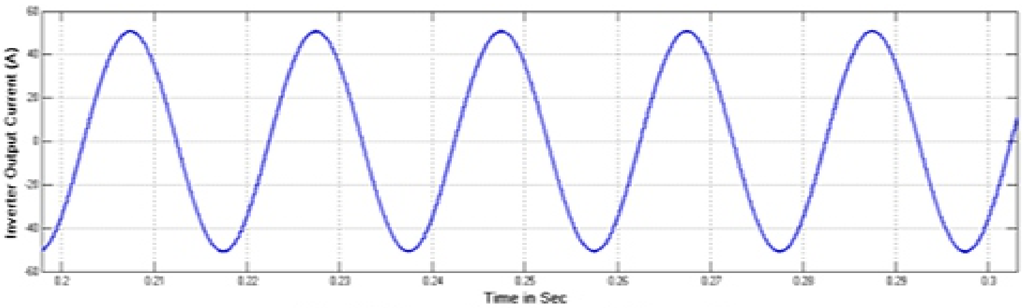
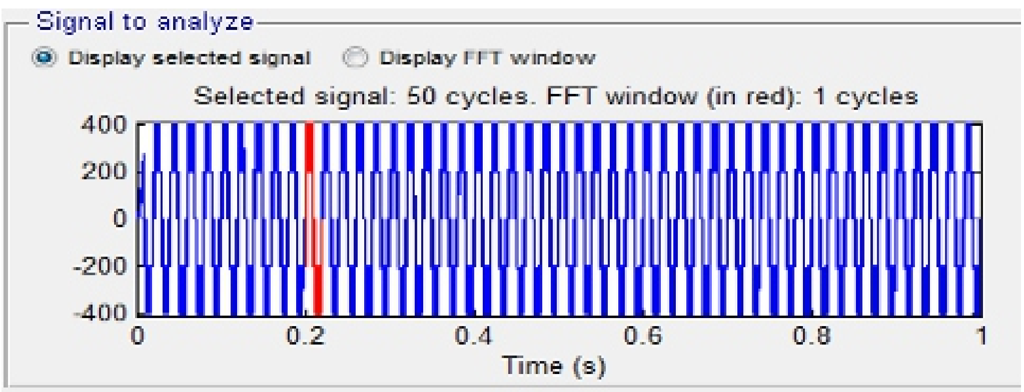


Fig.15: Inverter Output Current

Figure 15 shows the output current of five-switch five-level inverter with RL-load condition. The output current is sinusoidal with peak 50A. with RL-load, output current is smoothened by load inductor and hence load current is undistorted.



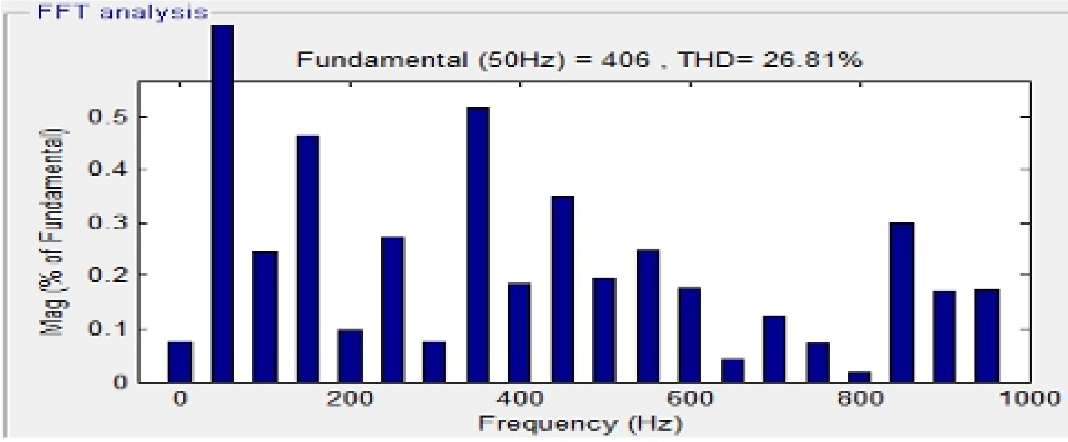


Fig. 16: THD in Voltage

Figure 16 illustrates the FFT window of harmonic distortion in inverter output voltage. Inverter output is five leveled output sisting of 26.81% distortion with respect to fundamental component.

Table 2 illustrates harmonic distortion analysis with different loading conditions.

Table 2: Harmonic distortion analysis

Load Condition	Inverter Voltage THD	Inverter Current THD
R-Load	27.04 %	27.04 %
RL-Load	26.81 %	0.66 %

5. Conclusion

Green energy solutions are of major interest in this era. This paper presents a MLI structure with five switches giving out five-level output from the inverter. PV system supplies the system through boost converter. Design of boost converter is depicted. The paper presents a simplified PWM (pulse width modulation) technique for PV fed five switch five-level inverter. Results are presented for the system considering R-load and RL-load conditions. Harmonic distortion analysis is tabulated and illustrates the harmonics in inverter current is reduced with RL-load condition, while THD in inverter voltage remains almost same. PV output and boost converter output are shown in result analysis. Digital control logic is explained in detail and switching pattern is shown.

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A review on Data Mining & Big Data Analytics

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A B S T R A C T

The time of enormous information is presently progressing. Be that as it may, the customary information investigation will most likely be unable to wrench such huge amounts of information. The inquiry that emerges now is, the way to build up an elite stage to effectively examine huge information and how to plan a suitable mining calculation to locate the helpful things from enormous information. To profoundly talk about this issue, this paper starts with a concise prologue to information investigation, trailed by the exchanges of enormous information examination.

Keywords: *Big Data Analytics, Data Mining.*

1. Introduction

As demonstrated by the estimation of Lyman et al., the information development and diffuse faster, an extensive bit of the data was considered modernized and what's more exchanged on web today. Truly, the issues of breaking down the expansive scale information were definitely not instantly happened yet rather have been there for a significant extended period of time in light of the fact that the generation of data is by and large considerably less requesting than observing pleasing things from the information.

The issues of looking at broad scale data, numerous beneficial methods [2], for instance, for inspecting, information build-up, and thickness based approaches, framework based systems, independent and defeat, incremental learning, and appropriated enrolling, have been in exhibited as shown Table1.Clearly, the eventual outcomes of these techniques speak to that with the capable systems near to; we may have the ability to separate the huge scale data in a sensible time. PCA [3] is away to diminish the data size to revive the technique of data examination. Data clustering is analyzing [4], be used to quicken the figuring the data examination.

Table:1: Popular Data Analytic Approaches	
Clustering	BIRCH
	DBSCAN
	IncrementalDBSCAN
Classification	Fast Neural Networks
	GPU based support vector machines
Association Rules	CLOSET
	FP-Tree
Sequential Patterns	SPADE
	SPAM
	ISE

In spite of the fact that the advances of PC frameworks and web advances have seen the improvement of processing equipment follows the Moore's law for quite a few years, the issues of dealing with the vast scale information still exist when we are entering the time of enormous information.

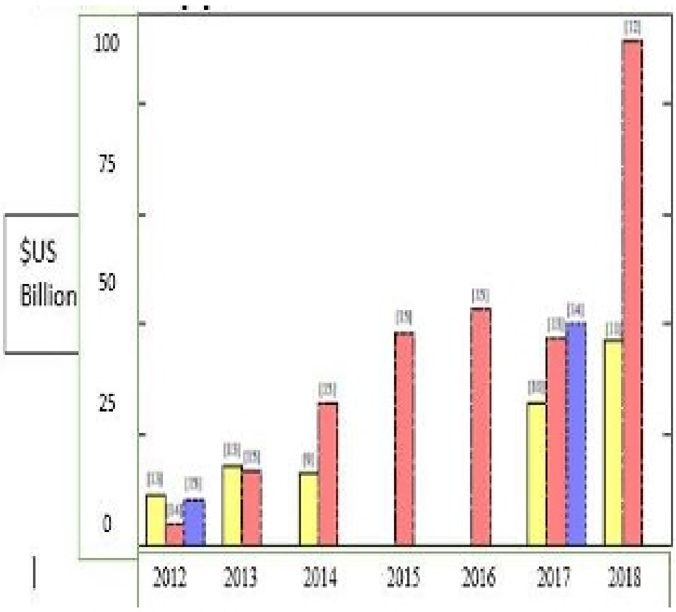

Fig 1. Trend of Big Data between 2012 and 2018.

As shown in Fig.1, despite the fact that the promoting estimations of enormous information in these investigates and innovation reports [5] are extraordinary, these forecasts more often than not demonstrate that the extent of huge information will be developed quickly in the approaching future. Without much of a stretch comprehend that huge information is of crucial significance all over the place. A various examines are in this concentrating on creating compelling advances to dissect the huge information. To examine in profound the huge information investigation, this paper gives not just a precise portrayal of customary huge scale information examination yet additionally a definite exchange about the contrasts amongst information and enormous information investigation system.

2. Data Analytics

As shown in Fig.2, with these administrators requires the information investigation framework to amass information and demonstrate the figuring out how to the customer. As demonstrated by our recognition, the amount of research articles and concentrated reports that consideration on data mining is regularly greater than the number stressing on various administrators, anyway it doesn't suggest that administrators of KDD are irrelevant. Substitute administrators furthermore expect the crucial parts in KDD process since they will unequivocally influence the last result of KDD.

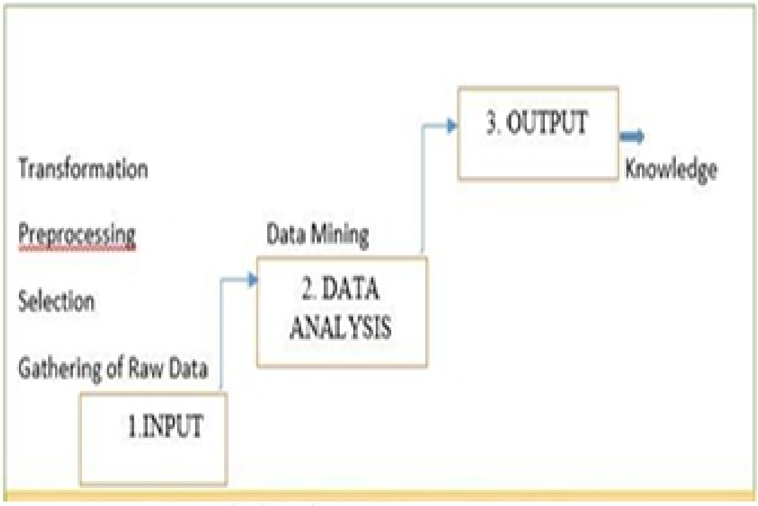

Fig 2. Knowledge discovery process in Data Bases

Gathering, selection and pre-processing are in the input part, in this manner; this accumulated information from various information assets should be incorporated to the objective information. The pre-preparing administrator assumes an alternate part in managing the information which is gone for recognizing, cleaning, and sifting the superfluous, conflicting, and inadequate information to make them the valuable information. After the determination and pre-handling administrators, the qualities of the optional information still might be in various diverse information positions; in this manner, the KDD procedure needs to change them into an information mining-skilled organization which is performed by the change administrator. The strategies for lessening the many-sided quality and cutting back the information scale to make the information helpful for information examination part are typically utilized in the change, for example, dimensional diminishment, inspecting, coding, or change.

The information extraction, information cleaning, information combination, information change, and information decrease administrators can be viewed as the pre-handling procedures of information examination which endeavors to them with the goal that they can be utilized by the accompanying information investigations. On the off chance that the information is a copy duplicate, deficient, conflicting, loud, or anomalies, at that point these administrators need to tidy them up. Separate helpful information from the crude information (additionally called the essential information) and refine

On the off chance that the information is excessively intricate or too expensive, making it impossible to be dealt with, these administrators will likewise endeavor to decrease them. In the event that the crude information hasmistaken or exclusions, the parts of these administrators are to distinguish them and make them steady. It can be normal that these administrators may influence the investigation consequence of KDD, be it positive or negative. In outline, the efficient arrangements are more often than not to lessen the many-sided quality of information to quicken the calculation time of KDD and to enhance the exactness of the examination result.

3. Data Analysis

Information investigation in KDD is accountable for finding the shrouded designs/rules/data from the information. The information mining methods [6] are not constrained to information issue particular strategies. Actually, different advances have likewise been utilized to investigate the information for a long time. In the beginning times of information examination, the measurable techniques were utilized for breaking down the information enable us to comprehend the circumstance we are confronting, for example, popular assessment survey or TV program rating. Like the measurable examination, the issue particular strategies for information mining additionally endeavored to comprehend the importance from the gathered information. After the information mining issue was introduced, a portion of the area particular calculations are additionally created. Researchers [7-10] apriori algorithm, machine learning etc., most information mining algorithms contain the initialization, information I/O, information examine, rules development, and rules update operators [12].

Clustering is the most identified information mining issues since it is utilized to comprehend the "new" input data. The essential thought of this issue is to isolate an arrangement of unlabeled info information 2 to k distinctive gatherings, e.g., for example, kmeans[11]. Classification is the inverse of what we discussed in light of the fact that it depends on an arrangement of named input information to develop an arrangement of classifiers which will then be utilized to characterize the unlabeled information to the gatherings to which they have a place. To take care of the order issue, the choice tree-based calculation [12], Naive Bayesian [13], and SVM are broadly utilized as a part of years. Not at all like bunching and arrangement that endeavor to characterize the information to k gatherings, are affiliation rules and consecutive examples centered on discovering the "connections" between the information. The essential thought of affiliation rules is discover all the co-event connections between the information. For the affiliation rules issue, the apriori calculation is a standout amongst the most mainstream techniques. All things considered, in light the fact that it is computationally extremely costly, later examinations have endeavored to utilize diverse ways to deal diminishing the cost of the apriori calculation;at that point it will be alluded to as the consecutive example mining issue. A few apriori-like calculations were displayed for understanding it, for example, summed up successive example and consecutive example revelation utilizing equality classes.

4. Big Data Analytics

These days, the information that should be investigated are not quite recently huge, but rather they are made out of different information sorts, and notwithstanding including spilling information. Since huge information has the special highlights of "enormous, high dimensional, heterogeneous, mind boggling, unstructured, inadequate, uproarious, and mistaken," which may change the factual and information investigation approaches. Despite the fact that it appears that enormous information makes it feasible for us to gather more information to discover more valuable data, truly more information don't really mean more helpful data. It might contain more questionable or irregular information.

For example, a client may have numerous accounts, or a record might be utilized by numerous clients, which may corrupt the exactness of the mining comes about. For example, protection, security, stockpiling, adaptation to internal failure, and nature of information [14]. The enormous information might be made by handheld gadget, interpersonal organization, web of things, mixed media, and numerous applications have the qualities of speed, volume, and assortment. Therefore, the entire information examination must be rethought from the accompanying points of view: Not the same as customary data analytics, for the remote sensor arrange information investigation, Baraniuk [15] called attention to that. This is on the grounds that sensors can accumulate substantially more information, however when transferring such huge information to upper layer framework, it might make bottlenecks all around.

From the assortment point of view, on the grounds that the approaching information may utilize diverse sorts or have deficient information, how to deal with them additionally get another problem for the information operators of data analytics.

The vast majority of the analytics on the customary information examination are centered on the outline and improvement of proficient and additionally successful "ways" to locate the helpful things from the information. Be that as it may, when we enter the time of huge information, most by far of the present PC frameworks won't have the ability to manage the whole dataset in the meantime; subsequently, how to plot a decent information investigation structure or platform3 and how to outline examination methods are both basic things for the information examination process.

4.1. Big Data Analysis Algorithms

In the age of big data, [17] conventional bunching calculations will turn out to be considerably more restricted than before in light of the fact that they ordinarily require that every one of the information be in a similar arrangement and be stacked into a similar machine to locate some helpful things from the entire information. Despite the fact that the issue of breaking down large-scale and high-dimensional dataset has pulled in numerous analysts from different traits in the most recent century, and a few arrangements have been exhibited as of late, the attributes still raised a few new difficulties in clustering issues.

Like the Clustering calculation for huge information mining, a couple of examinations in like manner attempted to modify the customary characterization a parallel figuring condition. In the layout of order calculation considered as the data that are amassed by disseminated information sources and they dealt with by different arrangement of students.

Analysts on recurrence design mining (affiliation regulation and successive example mining) were revolved around dealing with expansive scale dataset at the soonest reference point. Since the amount of exchanges are more than "many thousands", the issues about how to manage the expansive scale information were inspected for a significant extended period of time, for instance.

4.2. Community Detection Algorithms

Researches on community detection [18] were focused on the combination of multiple algorithms depends on top down bottom up approach many researchers have proved the efficienttime complexity in detecting similar communities in wide range of data.

Despite the way that the information examination these days may be wasteful for colossal data got from the earth, contraptions, frameworks, systems, and even issues that are extremely not exactly the same as standard mining issues, in light of the fact that couple of characteristics of enormous information likewise exist in the ordinary information investigation. A couple of open problems caused by the enormous information will be tended to as stage/system and information mining views of this fragment to clear up what issues we may confront in light of huge information.

5. Conclusions

In this paper, we looked considers on the information examination from the standard data examination to the current tremendous data examination. From the structure view, the KDD technique is used as the framework for these examinations and is thick into three areas: data, examination, and yield. From the motivation behind immense data examination framework and stage, the trade is focused on the execution orchestrated and occurs arranged issues. From the point of view of data mining issue, this demonstrates a brief prologue to the data and gigantic data mining counts which incorporates gathering, portrayal, and normal illustrations mining developments.

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A 500 Watts Single Stage Single Switch Soft Switched CCM PFC Flyback Converter with BCM Control

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A B S T R A C T

Single stage isolated AC to DC converters find prominence due to simplicity and efficiency in addition to economics. Boundary control Mode BCM Flyback converters are widely used for such applications up to power levels of 200 watts. For higher power levels, average current control mode PFCs are used and two stage conversion is incorporated. In this paper, a novel technique for building a single stage PFC with a Continuous Conduction Mode CCM Flyback AC DC converter is proposed for 500 watts power. A practicalsingle stage converter is built with power factor correction and input output isolation. The unique feature of the new configuration lies in having only one primary MOSFET switch and adapting BCM control in a CCM Flyback configuration and achieving ZVS and ZCS while in CCM operation. Proposed configuration is best suited for battery charger applications. Also, the absence of high voltage bulk capacitor at the mains input adds lot of advantages in terms of eliminating inrush current and saving PCB area. A working model of 130 V Dc output and 4.0A is built and the test data are presented depicting the complete soft switching of all power devices and exhibiting the efficiencies in excess of 95%.

Keywords: *Single Stage, Soft Switching, PFC, Power Factor Correction, Flyback Converter, CCM, BCM Control, Delay, efficiency, power loss*

1. Introduction

As the technology development is rapidly progressing, so is the utility of electrical energy. By the day, the number gadgets getting in to human lives is progressing at a steady pace. Thereby, in addition to the demand of producing additional energy, a large thrust is imposed on the improvement of energy efficiency of existing/upcoming gadgets and reduction of losses.[1]

The number of electronic gadgets increased imposing international agencies such as EN, VDE and CISPER [2], to define the interface specifications for electronic gadgets connected to utility mains. As a part of the specifications, it is mandatory that all electronic equipment consuming power of 75watts and more have to meet the power factor requirements and current harmonic distortion levels. The IEC specification IEC 61000-3-2 dictates the requirement of power factor.

2. Active Power Factor Correction

Most of the AC DC converters are Offline SMPS, meaning rectifying the AC input directly with a high voltage bridge rectifier following it up with a large filter capacitor. Under such conditions, current drawn from the mains is spiky and current is drawn for short durations only at the peak of input voltage. So, in the complete one rectified mains switching cycle say 10miiliseconds(For 50Hz), energy is drawn from the input only for a short duration and the rest of the time current is not drawn. Hence, this method turns out to be highly inefficient as most of the time input energy is not utilized. The ratio of peak current to average current is very high, to compensate the idle duration. These adverse factors can be conveniently corrected with active power factor correction.

Since the discontinuous input current has to be made continuous, Boost configuration DC-DC converters are well suited in PFC applications. Boost regulator input current is continuous because the output voltage is higher than the input voltage and load current is always flowing through the input [3].

Active Power Factor Converter power supplies can be classified as two types

a) Two Stage: This involves a front end boost converter which generates a regulated DC voltage of around 400V DC, from the rectified mains input voltage. Then a second level DC-DC converter is employed to generate the user needed output voltage with input output galvanic isolation. Variety of control ICs are available to actively correct the input current wave shape and power factor. The two stage PFC circuits are adapted for power levels of above 200 watts. Average input current control technique is used to achieve PFC and mostly the boost converter operates in the continuous conduction mode [8].

b) Single Stage PFC: For power levels of less than 200 watts, single stage PFC converters are in use. These converters achieve good PF and generate the user required low voltage with isolation. Though these units look simple and attractive because of one stage control, they are limited to low power levels. For such applications, Flyback converters with boundary control mode BCM with constant ON time are adapted widely in the industry. Umpteen control ICs for such scheme are available for commercial applications [4, 9].

Though there are some configurations, wherein a single MOSFET switch is used for Boost operation and the subsequent DC-DC conversion and categorized as single stage PFC converters for higher power [5], they did not gain much prominence due to two control loops and higher current stress in the single switch. Therefore single stage PFC converters are mostly the Flyback converters operating in the boundary conduction control mode (BCM) which achieve high PF and isolated output. The peak current in a BCM Flyback is very large compared to its average current and hence the limitation of lower power levels. Also, as the current ripple is high, these techniques require a larger line filters. However BCM fly back PFC converters are very popular and as stated earlier large number of control ICs for single stage PFC is available for industrial use.

Keeping all the above in mind, it is proposed in this paper a new and novel technique to build a single stage PFC AC DC converter with CCM fly back technology ,but with a BCM PFC controller IC. One the major advantage is attaining complete soft switching of all the power devices. Only a single MOSFET switch is used and no extra control algorithm or additional complexity in control is incorporated. A 500 watts converter is built with this scheme. Complete soft switching, a good power factor are demonstrated. The efficiency achieved is in the range of 95%.

3. Flyback Converters

A normal fly back converter in CCM control is shown in figure 1.

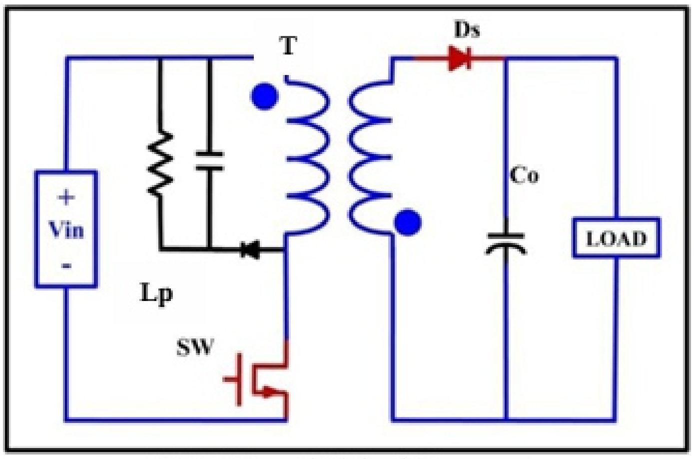

Fig 1: Normal Flyback Converter

MOSFET switch Sw is ON for Ton duration, where in energy is stored in the primary inductance Lp of the transformer T. During this phase, owing to the polarity, secondary diode Ds is OFF and output load is supplied by the reservoir capacitor C0 connected across output V0. Sw is OFF for a duration Toff during which the stored energy in Lp is delivered to load after turning ON the secondary diode. Ton +Toff forms the total time duration (T) of the switching frequency. Output voltage is regulated by a controller, varying the duty cycle D defined as Ton /T. Volt seconds across Lp are balanced over a switching cycle as

$$V_{in} * T_{on} = V_0 * T_{off} \text{ for a 1:1 transformer turns ratio} \quad (1)$$

Though we call it the transformer, in reality the fly back transformer is an inductor with two or more windings. Either the primary or the secondary shall be conducting at any given time and hence a DC bias is always present. This demands an air gap to be introduced in the magnetic path leading to increase in the leakage inductance. The energy stored in the leakage inductance can be large enough to destroy the MOSFET switch Sw if unattended. Therefore in normal Flyback converters, RCD snubber as shown in fig. 1 is incorporated to absorb the leakage energy.

It is very evident from the current and drain voltage waveforms of a CCM fly back converter that the switching is invariably hard in nature and also the snubber adapted is dissipative. This causes reduction in efficiency. Nevertheless, peak currents in the MOSFET are less compared to BCM [6].

BCM control ensures that at turn ON the current in switch is zero and hence reduced turn ON losses. Likewise the reverse recovery problem of the secondary diode Ds is automatically eliminated because the MOSFET is turned ON only after the diode/secondary current is reduced to zero. In this case peak currents are quite large.

4. Present Scheme

It is envisaged to build a CCM Flyback converter so that the peak currents are smaller. However, BCM control is advantageous due to avoidance of turn ON current and reverse recovery issue of output diode. Therefore, we propose a new scheme which is the combination of BCM and CCM. The configuration is shown in figure 2

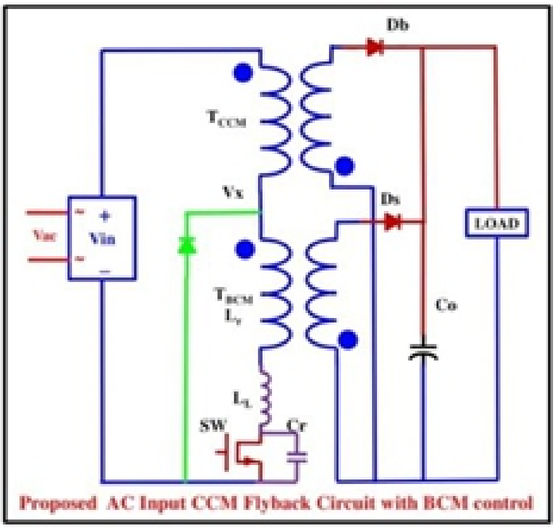

Figure 2: Proposed Configuration

Here in addition to the main Flyback transformer (TCCM), one other resonant Flyback transformer (TBCM) with a primary inductance of Lr is added and it is made to operate in BCM Secondaries of both the transformers are tied to output. Resonant Flyback transformer is a step down transformer with primary /secondary turns being "NB" and the turns ratio of transformer is NC. Turn OFF time of the main switch is dependent on detecting zero current in the resonant Flyback transformer TBCM secondary. ON time varies accordingly to regulate the output voltage. The detailed working is described below.

Sequence of achieving soft switching is defined by the following modes of operation of the converter.

Mode 1: Sw is OFF and the Flyback transformer secondary is supplying the load. Db is conducting and current in Lr is zero. Voltage at Vx is equal to Vin+NCVout. Sw is turned ON at this instance.

Mode 2: Sw turns ON with zero current due to Lr. The current in the Sw and also Lr begins to rise linearly. This mode ends when the current in the switch reaches Iinmin/NC. Iinmin is the current flowing in the secondary of the Flyback transformer TCCM to load.

Mode 3: The diode Db turns OFF with zero current. Current in switch Sw and Lr continues rise. This mode ends when the current is switch attains Iinmax and the controller turns OFF the switch.

Mode 4: Sw turns OFF with zero voltage due to Cr. Iinmax starts charging Cr. Voltage at Cr gradually rises and this mode ends when it reaches Vx

Mode 5: At this instance, the current Iinmax in the primary of flyback transformer is diverted to the output and the energy is transferred to the output. Lr continues to charge Cr and this phase ends when the voltage at Cr reaches NB*VOut+Vx. The time taken for Cr to rise from Vx to NB*VOut+Vx is much lower than the quarter of the resonant time of Lr and Cr.

Mode 6: At this instance the secondary of resonant flyback transformer TBCM develops a voltage equal to Vo and hence diode Ds conducts. Stored energy in Lr is transferred to output. This mode ends when the current in secondary of resonant flyback transformer reduces to zero and Ds turns off with zero current. Thus the energy stored in Lr due to Iinmax is divided in to charging Cr and the balance is transferred to output.

Mode 7: Resonance occurs between Lr and Cr and the energy from Cr is first transferred to Lr. Voltage at Cr decreases sinusoidal and the current in Lr builds up. The direction of the current in Lr is reversed now. This mode ends when the Cr voltage reaches Vx

Mode 8: At this instance Lr sees zero voltage across it and the current in Lr tries to remain constant.

Since Cr voltage cannot be held constant, it starts decreasing. Lr starts discharging Cr. If Lr and Cr values are properly chosen, then Cr voltage can reach to zero within the Sw OFF period. Time taken for the Cr voltage to come down to zero value starting at NB*VOut+Vx is half the resonant time period of Lr and Cr. At this instance Sw is turned ON again by the controller with ZVS and Mode 1 again repeats. The above, in terms of timing chart is explained below in Figure 3:

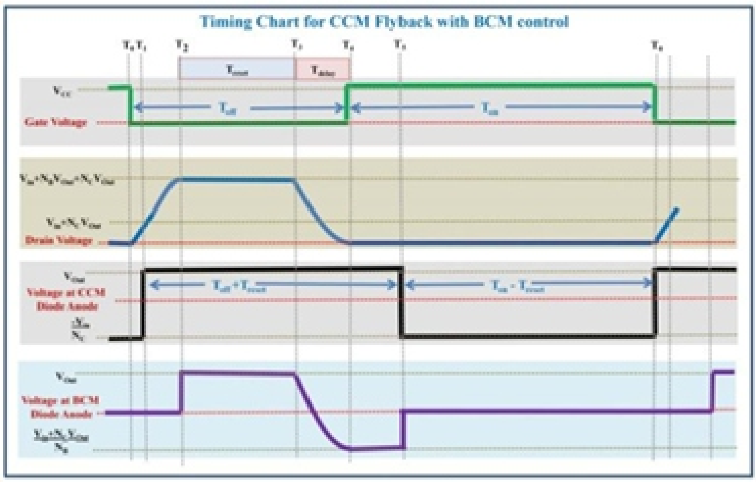

Fig 3: Timing Chart

Prior to T0 the MOSFET switch Sw was ON and the diode Db was OFF. Load current was supplied by the output capacitor and the input current was Iinmax flowing through the switch, flyback transformer primary and the Lr. At T0 switch Sw is turned OFF by the controller.

T0–T1: Due to the capacitor Cr, MOSFET turns OFF with zero voltage and the current Iinmax gradually charges the Cr and the drain voltage starts rising. At T1 the drain voltage reaches value Vx, the input voltage plus NC*VOut. At this point, the current in the TCCM primary Iinmax gets diverted to the output, by turning ON the Db diode. This duration can be approximated to linear rise in voltage due to large value of inductances and considering them as current sources.

T1–T2: In this duration, the resonance occurs between Lr and Cr and the drain voltage starts building up further due to the energy transfer from Lr in to Cr. This increase can happen till the energy in Lr reaches to zero value and the drain voltage reaches a peak value. Maximum value attainable at Cr over and above Vx is given by

$$Iin_{max} * \sqrt{(L_r/C_r)} \quad (2)$$

However by design when Cr voltage reaches Vx +NBVOut, the diode Ds conducts and clamps the drain voltage toVx +NBVOut at T2. This time duration shall be less than one quarter of resonant time period of Lr and Cr and is given by equation

$$(\pi/180)*\sqrt{(L_r*C_r)}* \text{Sin}^{-1} N_B V_{Out}/(Iin_{max}\sqrt{(L_r/C_r)})) \quad .(3)$$

Denoting this as tch it can be approximated to about 5% of the resonant period of Lr and Cr

T2–T3: During this period the balance energy in Lr is transferred to the output. At T3, the energy in the Lr is completely depleted and therefore the Zero Current Detection ZCD, signal changes its state from HIGH to LOW. This duration is titled as Treset and is determined by VOut, NB, Iinmax and Lr. Treset is approximated as Lr*Iinmax./VOut*NB

T3–T4: In a normal boundary mode controller operation, the MOSFET switch Sw is turned ON immediately, the moment ZCD signal changes its state from HIGH to LOW. But, in the proposed technique, a deliberate delay tdelay is introduced in turning ON the Sw after ZCD changes its state. The reason is explained here. At T3, the complete energy in transformer is depleted and the drain voltage at Cr is Vx+NBVout. The resonance starts between Lr and Cr at this point, because the MOSFET is still OFF and controller has not yet sent the ON signal. Drain voltage starts decreasing sinusoidally due to energy transfer from Cr to Lr. After drain voltage reaches Vx, Lr takes over and starts discharging Cr further.

The drain voltage will reach to zero value at T4 and the duration of T4toT3 is exactly the half resonant time period of Lr and Cr. The delay time tdelay is set to this half resonant time so that the controller turns ON the MOSFET at T4. This achieves the Zero voltage switching for the main switch .The switch OFF time Toff is fixed as T0 to T4. It is to be noted that at T4 when the switch is turned ON, the current in the Lr is zero and therefore the switch Sw turns ON with zero current, even though the diode Db is still conducting and the current in flyback transformer TCCM secondary is continuous and decreasing and is at a value Iinmin.

The ON time of the boost switch can be determined by applying the Volt second balance across the primary of flyback transformer..

Broadly, the Toff almost can be termed to be fairly constant (though it slightly varies depending on the load current) but Ton varies largely with line and load, to maintain the total soft switching and regulating the output voltage.

5. Implementation

The following design equations ensure the ZVS and ZCS for the main boost switch while operating in the continuous conduction mode. Prime facilitator for this is in maintaining approximately constant OFF time and allowing the switching frequency as a variable component.

Vin is the input DC voltage, VOut is the output,

Applying volt seconds balance for Flyback transformer,

$$V_{Out} * (T_{off} + T_{reset}) = V_{in} * (T_{on} - T_{reset}) / N_C \ldots\ldots \qquad (4)$$

$$T_{reset} \text{ Is approximated to } L_r * Iin_{max.} / V_{Out} * N_B \ldots \qquad ..(5)$$

$$T_{off} = T_{reset} + 1.1 \square \sqrt{L_r * C_r} \quad \ldots\ldots \qquad ..(6)$$

the turn off duration of the switch Sw with the Iinmax current.

A practical proto type AC DC converter was built with the above technique. Converter input was designed to be either 190V AC260V AC volts or 190V DC to 300V DC. Output was rated for 130V DC at 4.0Amps load. The BCM PFC controller IC FAN 7527 was used for control. All the fast recovery diodes were MUR860, and the Mosfet switch was a 1200V rated device. scheme incorporates a variable switching frequency to achieve soft switching of all the components. The proto type designed and fabricated was not provided with any line filter and the input current captured is without any line filter. The proto unit was tested to its full capacity and even heat run test was conducted at ambient temperature to record the temperature rise of power components.

6. Results and Discussion

The complete test data such as efficiency, PF and THD are reported. Efficiency measurements and also the gate and drain waveforms are captured for DC input to depict soft switching clearly. Fig.4 depicts the zero voltage turn ON and OFF distinctly at full load condition. The absence of Miller effect in the gate drive further emphasises the ZVS condition.

Table 1: Efficiency at Various Line and Load Conditions

Efficiency of the Converter at Various Line and Load Conditions

INPUT VOLTAGE	INPUT CURRENT	OUTPUT VOLTAGE	OUTPUT CURRENT	OUTPUT POWER	FREQ	EFFICIENCY
190 V DC	1.101A	130 V	1.539 A	200 W	125 KHZ	95.60%
220 V DC	0.95 A	130 V	1.537 A	200 W	133 KHZ	95.60%
300 V DC	0.703 A	130 V	1.539 A	200 W	200 KHZ	94.80%
190 V DC	2.796 A	130 V	3.89 A	500 W	66.6 KHZ	95.19%
220 V DC	2.410 A	130 V	3.89 A	500 W	80 KHZ	95.37%
300 V DC	1.76 A	130 V	3.88 A	500 W	108 KHZ	95.53%

Table 2: PF and THD at Various Line and Load Conditions

Power Factor and Harmonic Distortion Data				
INPUT VOLTAGE	200 WATTS		500 WATTS	
	PF	THD %	PF	THD
190 V AC	0.994	4.2%	0.999	12.2%
220 V AC	0.990	5.8%	0.998	10.3%
260 V AC	0.979	6.1%	0.997	8.5%

Fig. 4: Gate and Drain full Waveform At 220 V AC input 500W Load

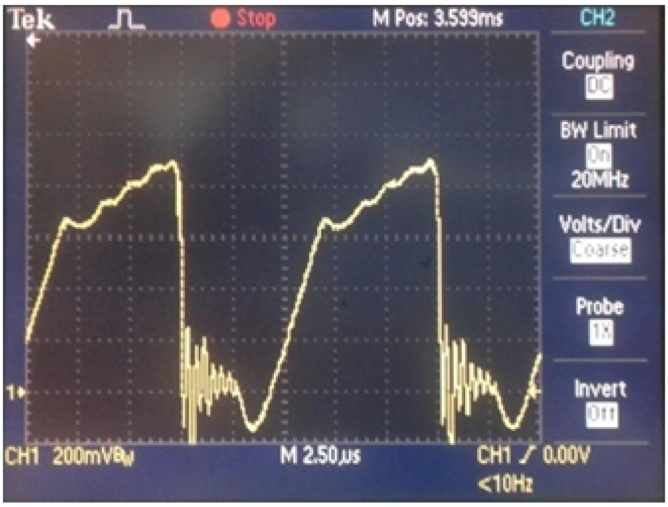

Fig. 5: Drain Current Waveforms At 220 V DC Input 500W Load

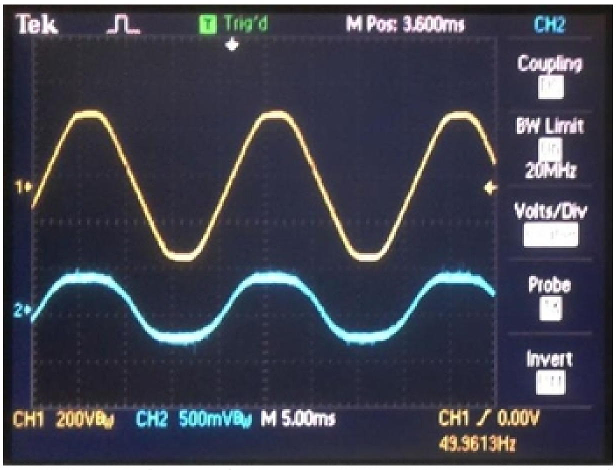

Fig. 6: Line Voltage and Current At 220 V AC input 500W Load

Fig.7: Product Image

The switch current shown in fig 5 demonstrates CCM mode of operation. At turn ON, zero current is seen and the initial slow rise has the slope due to Lr and the second slope is due to the primary inductance of TCCM. The fact that Db also turns OFF with zero current is established. Fig 6 depicts the input current obtained for an AC input voltage of 220 V AC and full load at output. The input current is near sinusoidal and it contains no high frequency component which gives thrust that the unit is in CCM and current ripple is low.Table1, reports efficiency figures achieved at various input levels for 200 and 500watt output. Results are very encouraging and clearly demonstrate the advantages of this scheme. Further Table 2 demonstrates the power factor and THD achieved for various input and output conditions. These measurements were conducted with Yokogowa WT210 power analyzer. The unit was run at full load continuously with natural convection cooling till the thermal equilibrium was obtained to estimate the power losses in transformers and the MOSFET switch.

MOSFET was mounted on a calibrated heat sink with thermal resistance of 8.4oC per watt. The thermal resistance of the transformers were taken as 18oC per watt from the data sheet. The estimated power loss in each of the transformer was around 3.5 watts and the Mosfet dissipated around 3watts.It is pertinent to mention here that the envisaged scheme demands a higher voltage Mosfet in the range of 1200V for 230V AC operation and130V DC output. The turns ratio NC was chosen as Unity and NB was 3.3 for 130

V DC output [7]. Fig 7 shows the image of the fabricated product.

7. Conclusions

A new technique is proposed to achieve total soft switching in a CCM flyback converter for power levels in the range of 500 Watts. A single switch, single stage, power factor corrected 500 watts converter is fabricated with the proposed scheme and the test data obtained are presented. Efficiency was around 95% and the PF was above 0.99. Total soft switching of all the switching devices is demonstrated. The simplicity and compactness of the present scheme can be comprehended by comparing the proposed one with already published literature [10]

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Performance and Emission Characteristics of Homogeneous Charge Compression Ignition Engine with Different Bio Diesel Fuels

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A B S T R A C T

In this paper the emission characteristics and performance of various bio diesel fuels (Tyre pyrolysis oil (TPO), Micro algae oil and Pig animal fat oil) were experimented. A single cylinder, water cooled diesel engine was modified in to homogeneous charge compression ignition engine (HCCI) with adopted port fuel injection (PFI) technique. The effects of air fuel ratio, intake temperature, injection pressure and EGR rate exhaust emissions were explained in a broad manner. The analysis of the exhaust emissions are integrated to oxides of Nitrogen (Nox), Carbon Monoxide (CO), unburned hydro carbons (UHC), smoke and soot. The performance analysis was also included on specific fuel consumption and break thermal efficiency. The basic requirements for HCCI engine is the homogeneous mixture preparation of air and fuel. This mixture formation was done by adopting port fuel injection technique and external devices were also used for bio diesel vaporization and mixture preparation. The combustion processes were measured with different EGR system. The experimental results of different bio diesel fuels with HCCI engine mode were recorded and evaluated. A small increase in CO and HC emissions were observed with increasing bio diesel content due to slow evaporation rate of bio diesel. A significant reduction in NOx emission was also observed with respect to difference in bio diesel blends. Micro algae oil was found more stable compared with other bio diesel fuels due to the property of fuel vaporization and low heat releasing.

Keywords: *Performance characteristics; emission characteristics; homogeneous charge compression ignition engine; micro algae oil; tyre pyrolysis oil;*

1. Introduction

Now a day's many automobile industries are looking for alternative technology in Internal Combustion (IC) Engine. A promising alternative is Homogeneous Charge Compression Ignition (HCCI) engines as it produces low emissions of NOx and particulate Matter (PM). In an IC engine, HCCI combustion can be achieved by premixing the air-fuel mixture and compressing it until the temperature is high enough for auto ignition (just like in the CI engine). The main challenges of HCCI engine are to control the combustion and to prepare the homogeneous mixture. In HCCI engine, a homogeneous charge is prepared by port fuel injector technique that injects the fuel on the inlet air stream to form premixed charge. The external mixture formation has the major problem of higher UHC emissions.

In 1997, Gray and Ryan used an electronic port fuel injector mounted 15 mm diameter upstream of the inlet valve; this was used for injecting fuel into the intake air for HCCI mode engine operation [1]. In 2000, Christensen and Johansson has been noted that with the variation in the equivalence ratio the CO and HC emissions also increases, as the combustion becomes highly incomplete due to lack of time for fuel mixing with air or by lack oxygen[2]. In 2002, Zhao H, Li J, Ma T, Ladommatos N conducted experiment on the 4 stroke multi cylinder gasoline engine with the CAI combustion and analysed the Performance and analysis[3]. In 2003, Tsolakis et al., to performed on The HCCI engine has at tracted a lot of attention in the combustion process for its low Nox emissions, low fuel consumption and high thermal efficiency characteristics[4]. In 2005, Odaka et al., was used earliest premixed/ direct injected system for HCCI operation. In this system, most of the fuel was injected into the intake manifold to form a homogeneous charge. The premixed charge was injected with small amount of fuel directly to the cylinder. The system achieved a reduction in both NOx and smoke emissions better than conventional diesel engine.

The major problem of modifying conventional diesel engine to HCCI mode engine is the controlling of the combustion and possible high emission of CO and HC [5]. In 2007, Chisti,Y al., In Bio diesel fuels consider an alternative fuels; bio diesel extracted from the crops, they concluded that the waste cooking oil and animal fat oil cannot realistically satisfy even a small fraction of the existing demand for transport fuels[6] and L. Xingcai et al., was conducted the experiment on HCCI engine and studded on the cycle-by-cycle variations of combustion by using primary reference fuels and their mixtures[7, 10]. In 2008, Himabindu et al has performed on the HCCI combustion of diesel fuel with external mixture formation technique revealed that NOx emissions reduced by 45-95% with 0-30% EGR at 75% load compared to conventional diesel combustion. In similar fashion, the smoke emissions reduced by 40-83% for the same load (75%) with 0-30% EGR compared to that of conventional diesel operation. Furthermore the recent studies on HCCI combustion characteristics using premixed charge disclosed significant reductions in both NOx and smoke emissions [8, 11, and 17]. In 2010, Ramesh, S et al., and 2012 singh AP were used HCCI engine and studied the performance of the engine using various bio diesel fuels [9, 12-14]. 2015 A.Avinash, et al., conducted experiment on Lean homogeneous combustion using external mixture formation technique used as an E-diesel fuel and performed emission analysis [15]. In 2017, Akhilendra pratap singh Partially used low volatility fuel and performed Homogeneous charge compression Ignition Engine[16]. The bio diesel produced from vegetable oil and animal fat using alcohol such as methanal, ethanol or butanol along with catalyst. The researcher focused on the production of bio diesel by using high oil content crops. Selected bio diesel micro algae oil is unicellular, photosynthetic micro organisms. They also grow extremely fast. Major problems in homogeneous mixture preparation: it required high intake temperature of air for external mixture preparation, this paper proposed preparation of the homogeneous mixture with the external mixture formation to control the combustion and ignition by using the ECU. The air heaters were used for heating the intake air based on the performance of the fuels. This research investigated different bio diesel fuels like TPO, Micro algae oil and Pig animal fat oil at constant speed of 1500 rpm. Exhaust gas recirculation was used up to 30 % to reduce the HC and CO of HCCI mode engine.

2. Experimental setup

The single cylinder, four strokes, water cooled, Direct Injection engine with eddy current load engine to modify into HCCI mode engine. It is adopted with external mixture formation technique as shown in Fig1. The engine specification details are listed in the Table 1. The amount for fuel injection and injection timing were controlled by ECU depending on engine speed and load. Eddy current dynamometer was controlled manually and the load applied was displayed in the digital meter on control panel. Experiment conducted at a speed of 1500 rpm, the conditions of engine running, speed and temperature (inlet air temperature, outlet air temperature, and combustion temperature) were displayed in the digital meter. The quantity of exhaust gases form the exhaust manifold was maintained and the fresh air temperature was measured through the temperature sensors and connected to the control unit. Exhaust gases were controlled by manual control valve. Increase in EGR increases inlet temperature and slows down the combustion processes. It resulted decrease in peak pressure and heat release and therefore longer combustion rate was achieved and efficiency increased along with EGR.

The transesterification process was conducted to extract the bio diesel fuels. The extracted bio diesel fuels were blended with the pure diesel fuel in the ratio of 20 % bio diesel and 80% diesel (B20) and 40% bio diesel fuel and 60 % Diesel fuel (B40). The properties of the bio diesel fuel were maintained as per the ASTM standard.

The properties of the diesel fuel, bio diesel fuel are listed in the Table 2, properties of the blended bio diesel fuels for B20 and B40 presented in the Table 3, 4 and 5. The better combustion was achieved by Exhaust gas recirculation process. Before to the manifold inlet, fresh air was mixed with 10 % of EGR. The experiment was conducted for different blends of the bio diesel fuels at constant operation of EGR with variation in the inlet temperature based on the performance of the bio diesel fuels. The performance and emission characteristics are compared between the unmodified direct injection diesel engine and modified HCCI engine with pure diesel fuels. The optimum operating conditions was also observed for the blended bio diesel fuels. Table 1 shows the exhaust emission ranges of Gas analyser and smoke analyser, it was used to measure the emission of HCCI-mode engine, such as NOx, PM, HC, CO_2 and CO. AVL smoke meter measure the exhaust smoke of the engine.

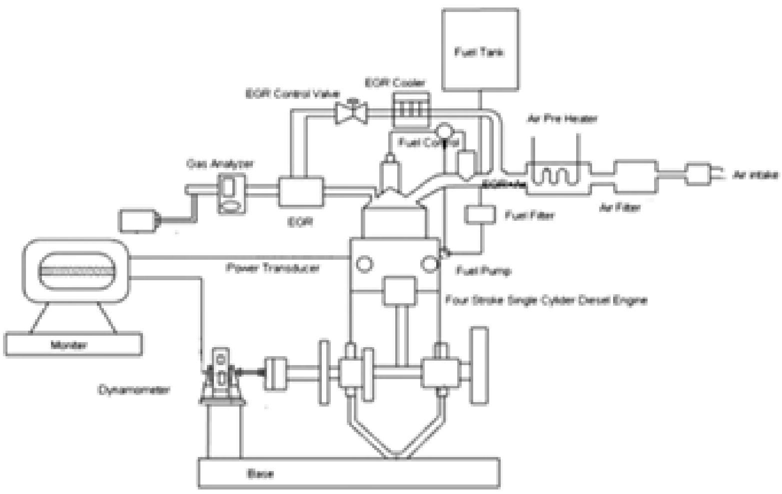

Fig1: Schematic diagram for experimental work

Table 1: Engine

S.No	Specification	Ranges
1	Make	Kirlosker
2	Type	4 S 1 C
3	Type of cooling	Water-Cooled
4	Stroke	110 mm
5	Compression ration	17.5:1
6	Bore	87.5
7	Rated Speed	1500 rpm
8	Rated power	4 KW
9	Orifice diameter	13.6 mm
10	Co efficient of discharge	0.64
11	Type of sensors	K-type
12	Fuel injection pressure	2.5-3 bars
13	Fuel injectors	4
14	AVL Di-Gas Analyzer	Nox – 0-500 ppm HC- 0-1000ppm CO-0-10% CO2-0-20%
15	AVL Smoke meter	0-100
16	Engine water flow	120lph
17	Inlet temperature measurement	RTD

Table 2: Fuel properties

S.No	Properties of fuels	Diesel	Micro algae oil	Tyre Pyroly-sis Oil (TPO)	pig animal fat oil
1	Density (Kg/m^3)	823	868	903	920
2	Calorific valve (MJ/Kg)	42.6	40.23	39.8	38.85
3	Kinematic viscosity at 40^oC	3.01	4.52	3.5	3.3
4	Cetane Num-ber	52	47	46	42
5	Flash point ^oC	51	113	46	44
6	Fire Point ^oC	57	120	52	51
7	Boiling point	180-360	220-430	100-360	70-360

Table 3: Main Properties of the Blended Fuels: Micro Algae oil

Properties of Fuels	B20	B40
Density (Kg/m^3)	837	843
Calorific valve (MJ/Kg)	44.3	43.6
Kinematic viscosity at 40^oC	2.67	2.93
Cetane Number	50	49
Specific Gravity	0.837	0.843

Table 4: Main Properties of the Blended Fuels: TPO

Properties of Fuels	B20	B40
Density (Kg/m^3)	887	894

Calorific valve (MJ/Kg)	37.75	35.12
Kinematic viscosity at 40^{o}C	5.6	5.82
Specific Gravity	0.887	0.894

Table 5: Main Properties of the Blended Fuels: Animal Fat Oil

Properties of Fuels	B20	B40
Density (Kg/m^3)	874	889
Calorific valve (MJ/Kg)	37.68	34.92
Kinematic viscosity at 40^{o}C	4.8	4.98
Specific Gravity of the fuel	0.874	0.889

3. Results and discussion

Single cylinder four stroke water cooled diesel engine was modified in to HCCI engine with port fuel injection system. This research was experimented with different bio diesel fuels likely TPO, micro algae oil, pig animal fat oil. The results were analysed for different operating conditions at the constant speed of 1500 rpm. The intake air temperature was selected based on the air- fuel ratio. At higher intake air temperature, richer mixture of fuel–air has advanced ignition timing and rate of pressure rise is also very high, which leads to knocking combustion. To avoid the knocking combustion, engine is operated at leaner mixture thus the IMEP is lower.

3.1 Break Thermal Efficiency

As shown in Fig 2 variation of the break thermal efficiency with three different bio diesel fuels on conventional engine and fied HCCI engine with variation of intake temperature based on the performance of the air- fuel ratio were recorded. Bio diesel fuel were blended for the ratio of B20 (diesel fuel 80 % and bio diesel 20%) and B40 (diesel fuel 60 % and bio diesel 40%). The increase in the break power resulted further increase in the break thermal efficiency of the fuel. The observed break thermal efficiency of the conventional diesel engine is 34.15 % and HCCI engine running with diesel fuels is 32.13 %.

Variation in BTE with the variation of the three different bio diesel fuels with blends B20 and B40 are shown in the Fig 2 and 3 respectively. All the four cases break thermal efficiency of the engine was increased with increase in break power. The BTE is observed all the blends of three different bio diesel fuels and the optimum level was achieved at B20. The BTE among three different bio diesel fuels, the algae oil is more compared to Pig animal fat oil and TPO at B20. Micro algae oil is 15.68%, 22.58%, 29.1% and 32.4% at different load conditions. Similarly the animal fat oil BTE at B20 is 22.56 % and for TPO at max load conditions reported 22.52 %.

Fig 3 shows the performance of three different bio diesel fuels blended with B40. The increase in the break power also increased the BTE, compared with B20 it is slightly decreases, because of viscosity of the fuel is higher than B20. Viscosity increases than BTE decreases, increases blends always decreases the BTE. Break thermal efficiency of algae oil is more than the remaining two different fuels as shown in the Fig 3.

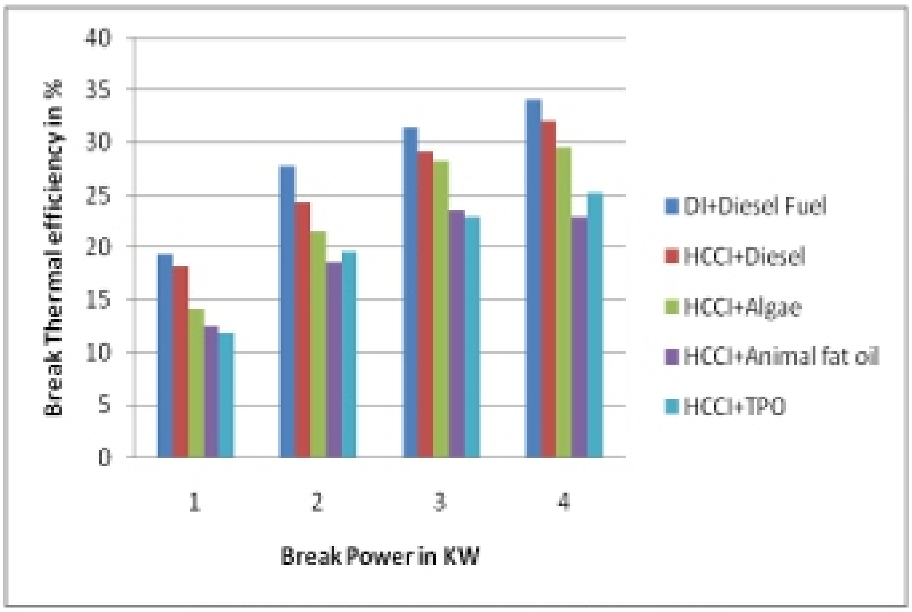

Fig. 2: Break thermal efficiency B20

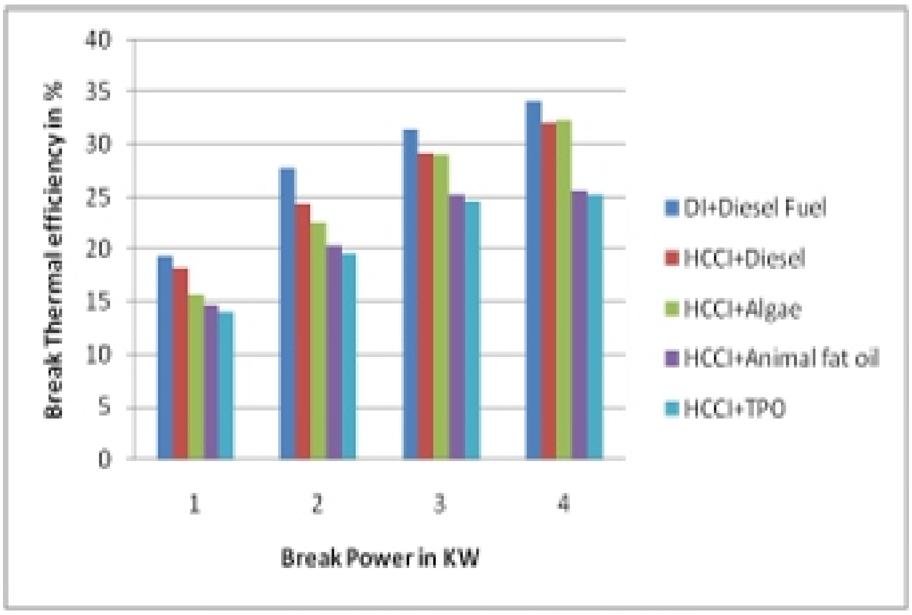

Fig. 3: Break power Vs BTE B40

3.2 Specific fuel consumption

In Fig. 4 and 5 shows the variation of the specific fuel consumption with variation of the break power on HCCI engine. In general HCCI engine have been consumed less amount of fuel than the conventional unmodified diesel engine. The Fig. 4 and 5 indicates that the bio diesel fuelled HCCI engine has higher specific fuel consumption compared to diesel fuelled HCCI engine, as the calorific valve of bio diesel fuel is lower than diesel fuels. The Biodiesel blends and it continuously increases with increasing biodiesel content in the test fuel were clearly observed. At higher blend (B40), SFC showed a different behaviour due to relatively dominant EGR than biodiesel content. Inlet temperature also effected the SFC consumption. Inlet temperature increases as the air molecules are extended and reduce the volumetric efficiency of the air. Minimum specific fuel consumption was achieved at part load condition. The experimental results in the graph indicated that among three different fuels the micro algae oil is encountered with less specific fuel consumption than other two fuels, as the calorific value of micro algae oil is more than other diesel fuels.

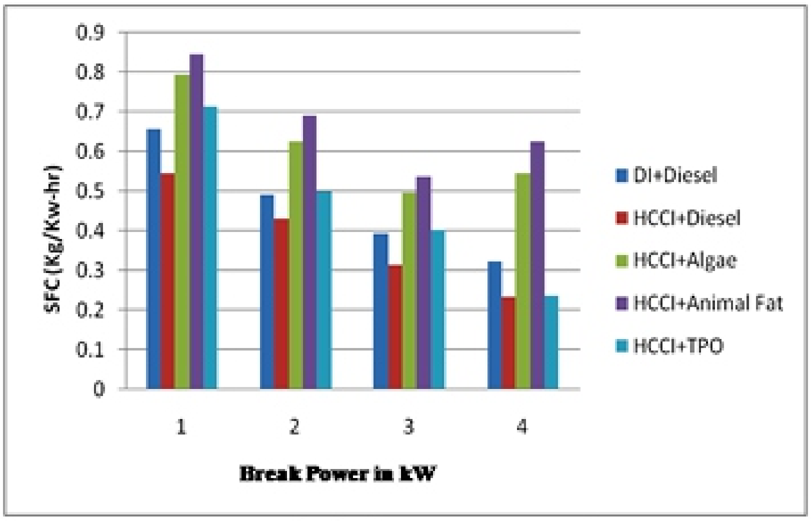

Fig.4: Specific fuel consumption with B20

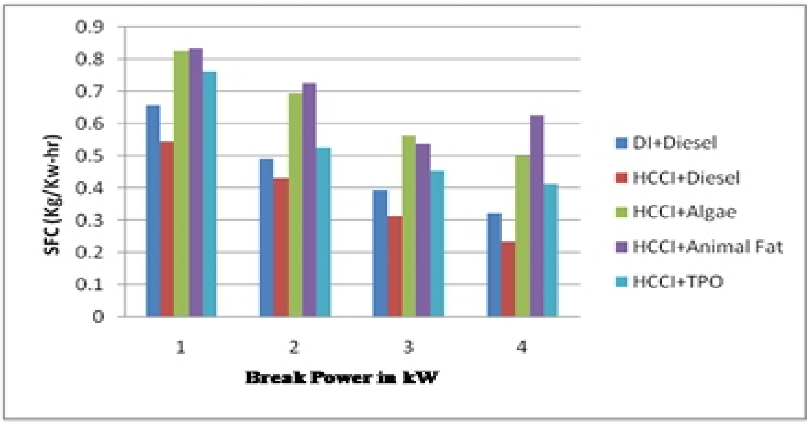

Fig.5: Specific fuel consumption with 40

3.3 Oxides of Nitrogen

The main advantage of HCCI engine is to reduce the oxides of the nitrogen. The figure 6 and 7 shows the variation of the oxides of nitrogen for different bio diesel fuels with B20 and B40 blends. The unmodified diesel engine is produced more oxides of nitrogen than HCCI mode engine. In bio diesel fuels the diesel engine duced high amount of oxides of nitrogen because of high cetanenumber. Also it reduced the ignition delay and ignition duration which produced high knocking and combustion temperature. Bio diesel fuels running with the HCCI engine mode produced less amount of NOx because of lean mixture proposition. It is observed from the figure 6, the oxides of the nitrogen were 200 ppm, 742 ppm, 948 ppm, and 1098 ppm in the diesel engine reduced to 84 ppm, 233 ppm, 459 ppm, 629 ppm at HCCI engine with diesel fuel. At HCCI engine mode the micro algae oil is produced less Nox compared to other fuels. Fig. 6 and 7 shows the oxides of nitrogen; the B20 produced less amount of NOx than B40.

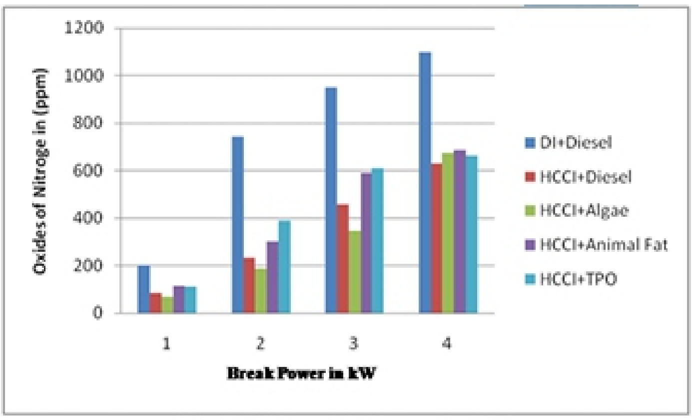

Fig.6: Oxides of nitrogen in B20

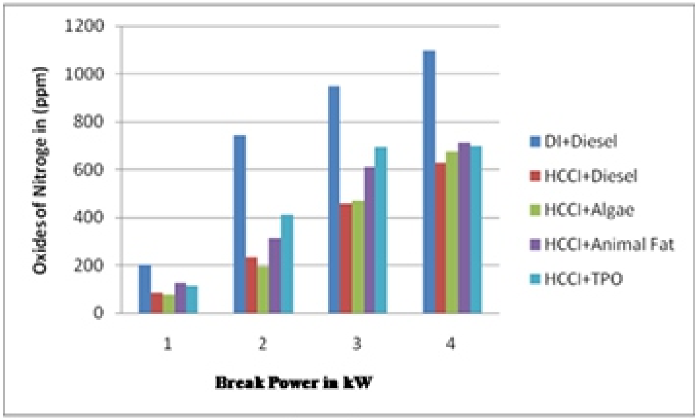

Fig.7: Oxides of nitrogen in B40

3.4 Carbon Monoxide (CO)

The emission of carbon monoxide has favoured the incomplete combustion and high temperature. The figure 8 and 9 shows the variation of CO with different bio diesel fuels with different inlet temperature of unmodified engine and HCCI mode engine. One of the major disadvantages observed on unmodified diesel engine was less CO than compared to HCCI Diesel engine because of air fuel mixture created before start of combustion processes in HCCI engine. To prevent the rich mixture in the combustion chamber, fuel was spared in to the entire cylinder to make the lean mixture. The Fig. 9 shows the bio diesel fuel running with the HCCI mode TPO produced less CO than other bio diesel fuels and also less than the fossil fuel. The reduction of CO in the emission influences the presence of rich mixture in the combustion chamber. The presence of oxygen is more in bio diesel fuels; engine with bio diesel fuels CO is converted to carbon monoxide. The Fig. 9 shows that the CO was reduced than other fuels. The blend B20 was optimal because of inside the combustion is prepared in rich mixture.

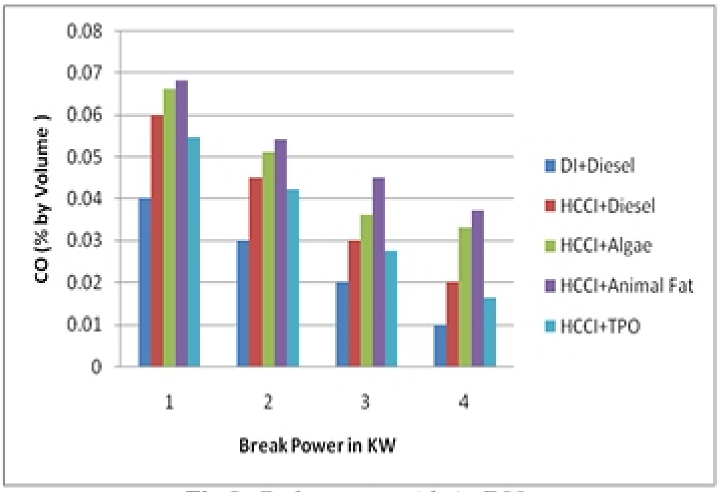

Fig.8: Carbon monoxide in B20

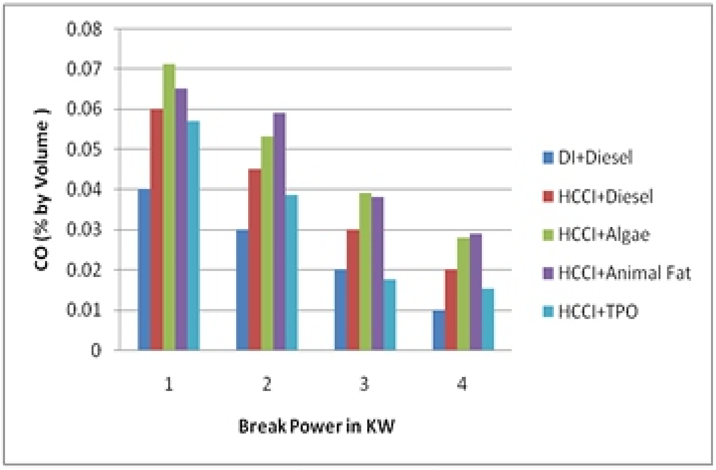

Fig.9: Carbon monoxide in B40

3.5 Smoke Density

The variation of the smoke density with the break power is shown in the Fig. 10 and 11. The smoke density produced in the unmodified engine was more than HCCI mode engine. Among three different bio diesel fuels the micro algae oil produced less smoke density because of more oxygen content in micro algae oil induced complete combustion in the engine cylinder. The Fig. 10 represents the smoke densities of different fuels with a blend of B20. The micro algae oil was reported with 8.4 HSU, 12.6 HSU, HSU and 26.2 HSU for different load conditions. Similarly the animal fat oil was recorded with 7.6 HSU, 14.5 HSU, 19.6 HSU, 31.2 HSU and TPO was recorded with 9.2 HSU, 17.5 HSU, 22.3 HSU, and 28.7 HSU for different load conditions. The performance of fuel property induced the variation in the temperature; temperature increases/ decreases influenced to decrease the smoke density up to 140 ºC based on fuel property. The Fig. 10 shows smoke density of the various bio diesels blend. The observed result indicates the smoke density was increased than B20 fuels, as because the viscosity of the fuels increased and therefore inside the combustion attained rich mixture.

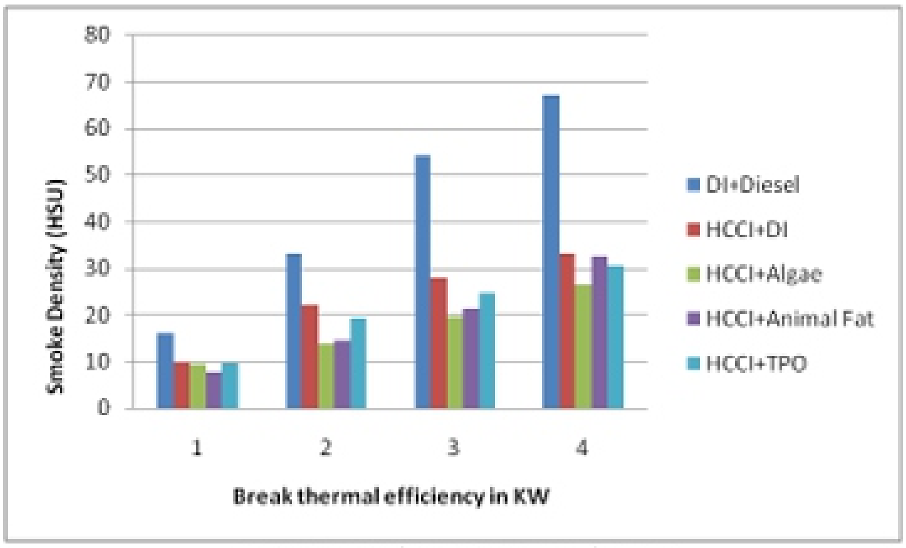

Fig.10: Smoke Density with B20

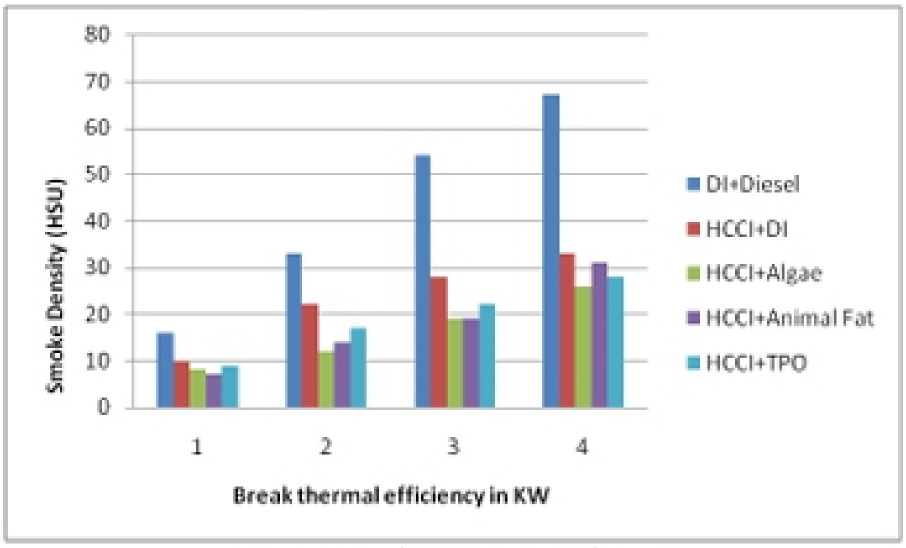

Fig.11: Smoke Density with B40

3.6 Hydro Carbon (HC)

Hydro Carbon is having disadvantage in the HCCI engine, because of HCCI engine all the operating condition is lean mixture preparation. Air/ fuel mixture has reduced the combustion temperature and pressure in HCCI engine mode. Low combustion temperature produced high amount of the Hydro carbons as shown in the Fig. 12. The variations of the hydro carbons of different bio diesel fuels with HCCI mode engine, at minimum load condition produced less amount of the HC at minimum load condition. However, the hydro carbons were increased along with the increase in load. The amount of HC can be controlled in the HCCI engine through recirculation of exhaust gas and increasing the inlet temperature; it causes to increases the combustion temperature to control HC in HCCI engine mode. The Fig. 12 and 13 indicates the variation of HC of different bio diesel fuels with blends of 20 % and 40 % of the bio diesel fuels. The 40 % of bio diesel fuels were produced less amount of the hydro carbons than the 20 % of the bio diesel fuels by circulating the EGR and inlet air temperature reduced 15 % ppm.

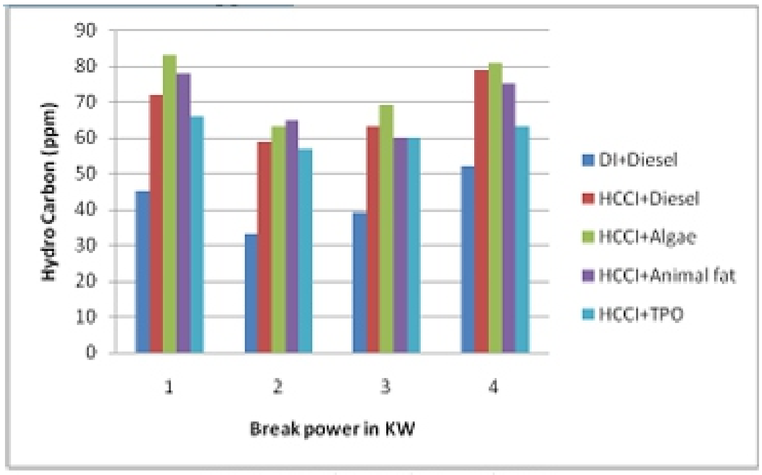

Fig.12: Hydro Carbon with B20

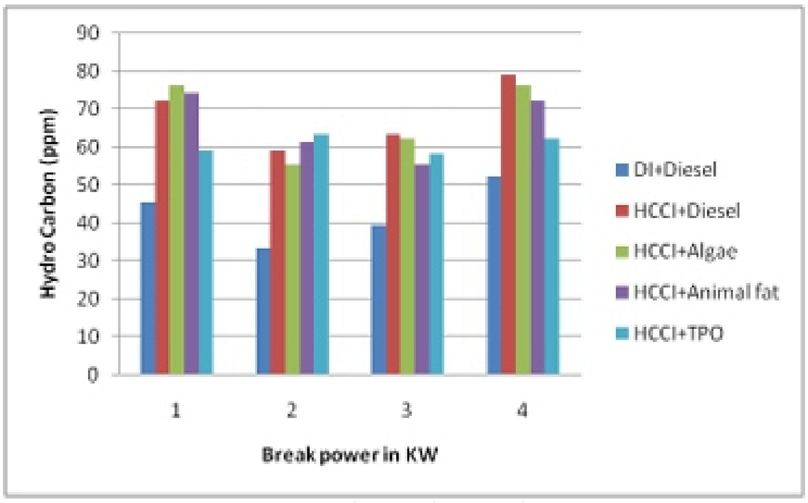

Fig.13: Hydro Carbon with B40

4. Conclusion

The performance and emissions of HCCI engine with different bio diesel fuels at constant speed 1500 rpm was experimented. Change of the inlet temperature based on the performance of the fuels and blended bio diesel fuels are 20% and 40 % with pure diesel. The achieved break thermal efficiency of the HCCI –mode engine was less than the unmodified diesel engine. The optimum break power observed at temperature between 120 - 140OC operated under HCCI mode with micro algae oil for blends of 20 %. The performance of algae oil was nearly equal to the diesel fuel. The specific fuel consumption of HCCI mode engine running with diesel fuels were less than bio diesel fuels. The fuel consumption of bio diesel fuels was continuously increased along with increase in their blends. Fuel consumption is optimum at B20 with variation of the temperature between 110 ºC to 130ºC based on the fuels properties.

The HCCI engine has very low NOx emissions compared to conventional diesel engine due to lean air/fuel complete combustion inside the engine operated low temperature. Less amount of the oxide nitrogen was produced in HCCI mode engine. Micro algae oil produced less amount of NOx than other two bio diesel fuels. Increases in loads produced high NOx in the HCCI mode engine.

The HCCI engine produced more CO than the unmodified diesel engine. CO was increased when the engine was running with lean mixture and produced low temperature. As the HCCI engine was completely operated under lean mixture condition, high amount of CO was produced. The excess of oxygen present in the bio diesel fuels reacted with carbon dioxide and resulted to more carbon monoxide. The results indicate that the TPO was produced less amount CO than other two fuels. Micro algae oil consists of more amount of oxygen.

The HCCI produced very less amount of the smoke density than conventional diesel engine, the HCCI mode engine with micro algae oil produced less smoke density at all load conditions.

The HCCI engine was also produced more amount of HC than conventional diesel engine. HCCI engine was attained 83.5 ppm and conventional diesel engine attained 51.2 ppm. The HC was reduced in HCCI engine under the bio diesel fuels operating conditions with minimum at 40 % of the blends.

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