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Analysis 0f Capacitor Charging Controller By Average Current-Mode Technique

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ABSTRACT

This paper emphasizes the explanation and implication of DC to AC converter, which is proficient of extracting extra power from rectifier. The output of the MOSFET bridge rectifier is given as input to this DC to AC converter. The piezoelectric generator comprising of piezoelectric crystal and a rectifier is connected in series a & parallel schemes to increase voltage & current as done in solar PV systems. The inverter performance and control techniques were evaluated. Simple topology, reliable operation and low cost are some of the reasons that make the Hard- switched inverters very popular. This inverter is tested with time and the technology has reached a level of maturity. However, the hard switching emits Electromagnetic Interference (EMI) and increases loss in the system.
Keywords:- Piezo electricity, CCC

INTRODUCTION

External sources of energy include solar power, thermal energy, wind energy, salinity gradients, & kinetic energy. This energy is captured & stored for use in small, wireless autonomous devices such as wearable electronics & wireless sensor networks. Energy harvesters supply a small amount of power to low-power electronic devices. While input fuel for some large-scale generation, such as oil, coal, & so on, is expensive, energy source for energy harvesters is present as ambient background & is free. Energy harvesting from the surrounding environment has been a research focus for many years. The idea of harvesting energy from environment & running a device without a battery is appealing for low-power electronic applications. Energy harvesting has emerged as a viable option for low power applications due to the slow advancement of battery technology and development of low power semiconductor technology. Energy harvesting systems can be based on a variety of sources, including kinetic energy from wind, waves, gravity, and vibrations, as well as electromagnetic energy, thermal energy, atomic energy, and biological energy.

Simple topology, reliable operation and low cost are some of the reasons that make the Hard-switched inverters very popular. This inverter is tested with time and the technology has reached a level of maturity. However, the hard switching emits Electromagnetic Interference (EMI) and increases loss in the system. Therefore, the switching frequency of the inverter may not be increased beyond a few kilohertz. A paradigm shift was necessary to look for new inverters that operate well at higher frequencies with definite advantages like low filtering requirement, higher efficiency, lower size and cost, reduced EMI, etc. This welcomes the further investigation on inverters unearthing various Soft switched versions of the network. However, this is at the cost of high voltage or current stress for the switching devices or increased device count. In addition, the soft switched inverters prefer a pulse density modulation that makes the effective frequency far less than the switching frequency. Different Soft-switched topologies and Zero-Voltage- Switching (ZVS) / Zero-Current-Switching (ZCS) based Pulse-Width Modulation (PWM) controllers are regularly reported to take care of these limitations. On the other hand, multilevel inverters have better band-width, reduced EMI and THD. Efforts are put towards applying space vector PWM to optimize the switching frequency for a desired performance. However, such inverters require more number of devices and are not suitable for low power applications.

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ALTERNATIVE ENERGY RESOURCES PIEZO ELECTRICITY

Piezoelectric energy is produced by translating mechanical vibrations into an electrical charge by subjecting a material to severe strain under extreme pressure. The quantity of energy gathered is affected by force used to distort the material, as well as amount & kind of deformation on the crystal arrangement of material & frequency of vibrations to the material. As a result, potential for piezoelectric energy harvesting is significantly larger than that of alternative energy harvesting methods, with components capable of supplying up to 70% of their charge.

Quartz & ferroelectric crystals such as Tourmaline and Rochelle salt are examples of piezoelectric materials. The most widely used piezoelectric material for energy harvesting is ceramic lead zirconate titanate (PZT). To reduce losses, PZT materials are created by adding dopants to Barium titanate crystals. PZT materials have the advantage of being able to be manufactured in any shape and size, which allows them to be optimised for specific applications.

Piezoelectric materials are malleable, chemically inert, & resistant to extreme temperatures & pressures. All of these key benefits consider piezoelectric energy harvesting to be the most promising opportunity in industrial applications. PZT materials can be repeatedly deformed to create energy & power devices, with sensors and industrial equipment being common applications.

Piezoelectric ceramic materials generate energy by converting mechanical energy into electrical energy. Even minor deformations can cause a detectable charge. As a result, a PZT material can produce enough voltage to power a small Wireless Sensor Network (WSN). The energy produced can then be stored in a capacitor or a battery. However, the performance of any power generated in this manner is governed by a number of factors, including shape of the PZT transducer, style in which transducer was installed, & nature of electrical load.

Impedance, which is measure of resistance to flow of alternating current to load, is another important factor to consider. To maximise energy transfer to the reservoir capacitor, electrical impedance of the piezoelectric component must be matched to electronic recovery system when the current is generated. Otherwise, if the charge is not allowed to flow away quickly, electrical field generated will tend to dissipate through electronic components. As a result, high-pressure applications must be subjected to a quick impulse to ensure that charge does not dissipate too quickly. The electronic recovery circuit's preference and intent are equally important. To reduce leakage currents and increase energy transfer efficiency, components must be carefully considered.

There are numerous applications for piezoelectric energy harvesters. The progression has some of highest efficiencies & power outputs by dimension & expenditure, making it extremely appealing to those looking for a high-performance, cost-effective solution. Rather than focusing solely on energy savings, the environmental benefit of replacing with batteries, other charging methods, and their associated replacement costs.

LITERATURE REVIEW

Meng Di Yin et al. (2016) begin by creating a pulse-based charging technique for batteries, which has been demonstrated to be a fast & efficient way. In order to inject maximum charge current into the battery cells, pulse frequency for managing battery charge time is dynamically adjusted within a particular range. The newly devised charging algorithm is roughly 18.6 percent quicker than & usual Constant-Current (CC) charging technique with a moderate temperature rise. The implemented charger system, which is based on & proposed dynamic frequency and duty control while accounting for cell polarisation, charges to approximately 80% of its maximum capacity in less than 56 minutes & involves a maximum temperature rise of 13°C without causing damage to battery.

Using Maximum Power Point Tracking (MPPT) approach, Xuan-Dien et al. (2014) optimised Piezoelectric Energy Harvesting Systems. By adjusting rectifier's DC to DC converter, a full-bridge rectifier is utilised in combination with an MPPT unit to maximise extracted power. Regardless of load state, extracted power efficiency of rectifier is always more than 80% when the MPPT module is employed. To modify output voltage to correct level, a second DC to DC converter is also employed. According to modelling findings, system may collect up to 51 W of electricity while maintaining a total efficiency of 64%.

Szarka et al. (2012) provide an overview of power conditioning techniques used in energy harvesting systems. The emphasis is on low-power kinetic energy harvesting systems with capacities less than 10mW. The functionality of published concepts is classified, & the results are

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compared. The various techniques described are compared to an optimum load in terms of complexity, efficiency, idle power consumption, start-up behaviour, and harvester utilisation. This research article concludes with a discussion of power management techniques aimed at increasing extracted power and energy harvester utilisation.

Sriramdas, et al. (2017) have proposed Ascending and presentation study of mems PEEH, the VEH have remained impressively assumed to engage energy since mechanical vibrations as well as change addicted to electric energy. This technique is to study the electric energy produced by an amorph that can be prolonged to bimorphs or multi-layer harvesters are discussed here. This process presents the smallest number of probable variables that rule the electric energy established by means of a harvester. This technique offers incredible ruler in the scheme, nevertheless of the scope and material, causing in a complete method of changing the presentation of a PEEH.

Iqbal, Muhammad, et al. (2018) have introduced, Hybrid vibration and wind EH using united PE and EM transformation used for bridge health observing presentations, an original multimodal HBEH combined with PE and EM transformation is described. The structural design, and categorization of the harvester is described here. The planned Hybrid BEH contains of a stable magnet, a looped coil, a PE plate also two cantilever beams fond of to the base supporting frame. The higher cantilever farms the stable magnet and airfoil by means of the tip mass. A PE plate was attached on the beam closed to the fixed end. Moreover, lesser beam clamps a spiral coil. The coil is tuned in such means of open and close by the stable magnet. In hybrid stimulation of 0.4g and at 6m/s, the EM producer create voltage of 483mV, while, PE producers manufactured 6421mV which is similar input investigational state.

Zhao, Dan, et al. (2018) have introduced Theoretic displaying and examination of 2-degree hybrid PE EMVEH with a determined beam, an original 2-degree hybrid PE EM-VEH is introduced to realize improved EH efficiency. This consists of a major PEEH system which an EM mechanism was doubled to increase integrating electrical energy output also determined beam is attached to increase the operational BW by prompting non-linearity. Frequency bend stimulation check is directed by setup at a stimulated acceleration about 0.3g also the demonstrated outputs are obtained as two resonant regions by way of highest resultant energy of 5.4milliW and 6.49milliW correspondingly, and the operated BW is to be improved by means of 8 Hertz. However, stiffness of driven beam k3 is adjusted also crack among primary and driven beam is and presentation of harvester are able to improve further.

C.Tchawoua, et al. (2018) have introduced Hybrid EM and PEVEH with Gaussian white noise excitation. The dynamical activities of the hybrid EH in GWN with probable methodology are investigated. Here they found that the impact of this type of noise and the dynamic forces of the non-linear EM system is displayed and the stochastic bifurcations are categorized by a quantitative variation of static probability distribution. In addition, the evaluation among energy is achieved through the fusion method, PE and EMEH demonstrates the importance to construct the fusion method. The logical outcomes approve very fit by mathematical replication.

Adu-Manu, et al. (2018) have introduced EH-WSNs, Evaluation of WSNs which is critical in supportive nonstop ecological observing; wherever sensor nodules are organized also it is essential to keep on in operation to assemble and transmits the documents on or after the location towards the base-station. The setting out of EH in ecological systems reduces dependence upon the sensor nodules over the battery power, extremely decreasing the cost to repairs the essential to change batteries. Finally, they presented recent applications of EH of WSNs for environmental presentations. In spite of large body of exertion in this region, there are various challenges which is essential to be lectured and to create Energy Harvesting of wireless sensor networks mainstream.

Mohd Faizul MohdSabri, Mahidur R.Sarker, and other researchers (2019) As electricity demand grows, energy harvesting (EH) from underused natural waste energy sources is becoming increasingly widespread. Depending on environmental circumstances, the sources have the capacity to provide micro to milliwatts of electricity. Following a thorough analysis, it was revealed that current technologies are capable of EH by utilising piezoelectric components; however, the systems' consistency and stability are not yet up to grade. In this work, vibration-based PEHS were examined for optimization technique application to increase their performance. This review concentrated on a variety of issues & recommendations for next-generation EH based on vibration-based piezoelectric components.

Mahidur R. Sarker & others (2021) presents an overview of EMEH approaches for autonomous sensor applications (ATS). When utilised to power such ATS technologies or to transfer mechanical

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energy to electrical energy, electromagnetic devices offer enormous potential. As a result, it consumes less power & is exceptionally steady while collecting energy from environment with limited ambient energy sources. The study focuses on EMEH circuits, low power EMEH devices, power electronic converters, & controllers utilised in a variety of applications, as well as their influence on energy conservation, advantages, & disadvantages. The study's ultimate objective is to create a clever, low-voltage electronic circuit for a low-power sensor that gathers electromagnetic energy. This review also covers a number of difficulties, as well as potential EMEH for low-power autonomous sensors.

SCOPE AND OBJECTIVE

Hard-switched inverters are popular for a number of reasons, including their simple topology, dependability, and low cost. This inverter has been tested and the technology has matured over time. Hard switching, on the other hand, causes EMI & increases loss. As a result, switching frequency of inverter should not be increased beyond a few kilohertz. To look for new inverters that operate well at higher frequencies and have definite advantages such as low filtering requirements, higher efficiency, smaller size & cost, lower EMI, and so on, a paradigm shift is required.

This drives more study into inverters, which has resulted in development of several Soft switched variants of network. However, this comes at cost of higher device count or high voltage or current stress for switching devices. Soft switched inverters also benefit from pulse density modulation, which lowers effective frequency to a fraction of switching frequency. To solve these restrictions, various Soft-switched topologies & Zero-Voltage-Switching (ZVS) / Zero-Current-Switching (ZCS) based Pulse-Width Modulation (PWM) controllers are constantly published.

In contrast, multilevel inverters have a wider bandwidth, lower EMI, and lower THD. Using space vector PWM, efforts are being made to optimise switching frequency for a desired performance. Such inverters, however, necessitate a greater number of devices & are not suitable for low-power applications.

This study looks at typical PWM inverters from a new angle. Given that majority of inverters employ a PWM signal to drive a L–C filter, performance of filter is crucial. A larger inductance in filter not only increases size & expense, but also affects inverter's dynamic performance. As a consequence, this paper proposes a new algorithm for realising inverter functioning utilising a Controlled Capacitor Charging (CCC) technique.

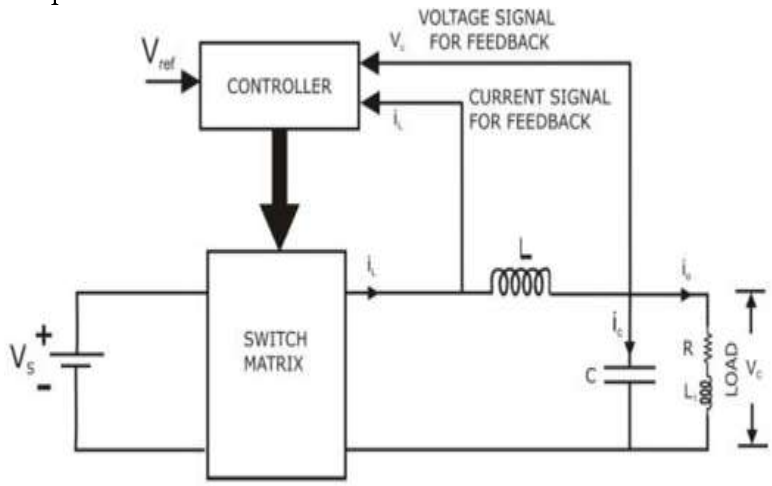

FIGURE 1 SCHEMATIC DIAGRAM OF THE CCC INVERTER

In this method, a capacitor is charged and discharged in a controlled manner to create required waveform at & output. The inverter is purposely operated in Discontinuous Conduction Mode to optimise performance & controllability (DCM). As a consequence, when a device is turned on, the ZCS is automatically realised. It is worth noting that capacitor-charging power supply have garnered a great deal of attention in literature. They were, nevertheless, employed in pulse-power applications where a capacitor of appropriate scale is charged for a longer length of time & energy in capacitor is swiftly released to a load when required. Such a device is inappropriate for providing sinusoidal power delivery.

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The authors previously reported performance of a single-phase inverter based on regulated capacitor charging, but dynamic performance was not provided. The dynamic performance of the CCC inverter is discussed in this research article.

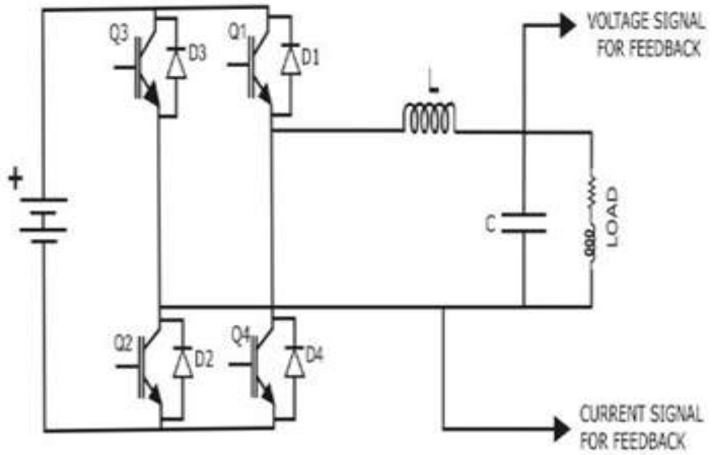

FIGURE 2 CONFIGURATION OF SINGLE-PHASE CCC INVERTER

SINGLE PHASE INVERTER TOPOLOGY

A current source & a switching mechanism are required for capacitive-charging inverters to apply positive or negative current pulses to charge capacitor (C) in a regulated way. The capacitor is connected in series with the load. As a result, the load voltage and capacitor voltage are synonymous, and the terms (load voltage and capacitor voltage) are used interchangeably. To limit the charging current of a voltage-fed inverter, an inductor (L) can be used.

As a consequence, CCC Inverter for a Voltage-fed Converter may be read as shown in Figure 1, where the Switch Matrix is made up of switching devices that apply a positive, negative, or null voltage to the L–C load network. Figure 2 depicts a single-phase CCC inverter arrangement. The values of L and C are influenced by a variety of parameters, including switching frequency, peak output voltage, & load to be provided. In single-phase topology, Inductor-Current & Capacitor-Voltage signals are employed for feedback.

CAPACITOR-CHARGING CONTROLLER

Capacitor-Charging controllers function as a tracking mechanism to generate any smoothly varying reference waveform by operating the inverter in various modes as needed. As a result, for the controller to function properly, a reference sinusoidal wave at power frequency (i.e., 50 Hz or 60 Hz) is required. The controller generates PWM signals and activates the appropriate switches using this signal as a reference. To increase dynamic performance & minimise inductor size, the inverter can be operated in DCM mode. The controller continually checks inductor current to guarantee optimal operation of the DCM. When inductor current is zero, the switch is only activated. The Voltage-mode control compares the output voltage to a reference voltage.

The resultant signal, which has been adequately adjusted to minimise instability, acts as PWM modulator's control signal. Average A little more complex control approach is current mode control, which involves a pair of Nested-loops. The inner loop produces an error signal by subtracting the inductor current from output of outer loop, & error signal is produced as a voltage-mode control. When it comes to selecting component values to optimise loop speed, current-mode control has a lot of benefits over voltage-mode control, & proposed inquiry is largely focused with this sort of control.

DESIGN PARAMETERS

To synthesise a desired voltage at output, suggested approach requires a regulated current and a capacitor. Figure 3 shows the CCC from a voltage source.

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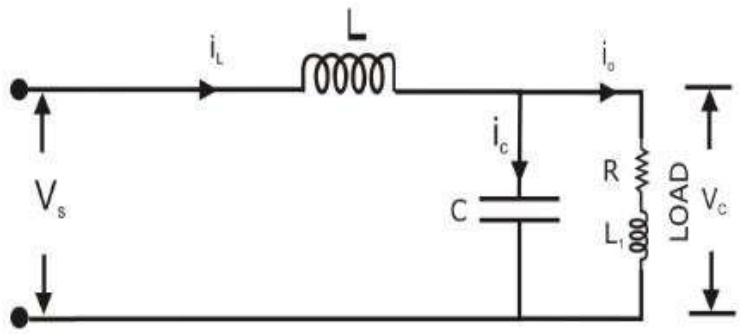

FIGURE 3 CCC FROM A VOLTAGE SOURCE

The inductor L contributes to charging/discharging current limitation. The capacitor voltage is fed back to compare with a corresponding reference waveform after the load is connected across it. Assuming ideal components, the network in Figure 3 can be deduced as follows.

$$v_c(n) = v_c(n-1) + \frac{1}{C}\int_{t_{n-1}}^{t_n} i_c(t)dt \quad (1)$$

$$i_c(t) = C\frac{dv_c(t)}{dt} = i_L(t) - i_0(t) \quad (2)$$

$$Ri_0(t) + L_1\frac{di_0(t)}{dt} = v_c(t) \quad (3)$$

$$L\frac{di_L(t)}{dt} = V_s - v_c(t) \quad (4)$$

The goal is to keep the voltage across the capacitor close to reference voltage by charging & discharging it appropriately using switches Q1 to Q4. The devices' switching patterns are adaptive & determined by nature of input voltage, LC components, & load, which is an important feature of this scheme.

The inverter must flip from one mode to other based on profile to be obtained & values of L & C. The Average Current-mode controller determines how long inverter will remain in any mode. Using

Equation (1) to Equation (4) & applying the proper sign for V_s during powering & regenerative modes, general1equation, describing dynamics of capacitor voltage, is found as:

$$v_c(n) = v_c(n-1) + \frac{1}{C}\int_{t_{n-1}}^{t_n} i_c(t)dt - \left(\frac{V_s}{RC}\right)(t_{on} - t_{off}) + \frac{L_1}{RC}[I_o(n) - I_o(n-1)] \quad (5)$$

RESULTS

In this part, a computer simulation of a controlled-capacitor-charging type inverter was done to assess its performance using the MATLAB Simulink software package for single phase. The simulink models of a CCC type single-phase inverter without & with a controller as an open-loop & closed-loop circuit are shown in Figures 4 & 5.

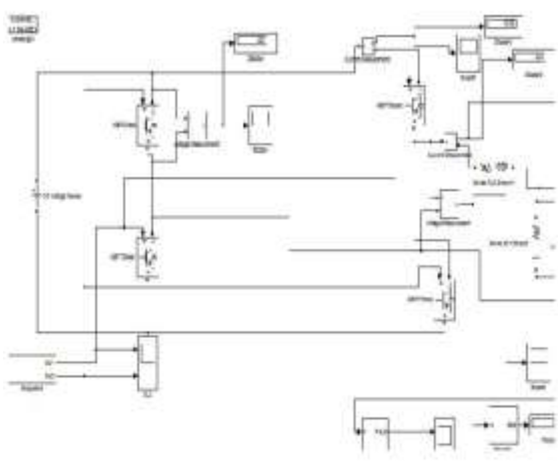

Figure 4 the simulink model of CCC type single-phase inverter without controller

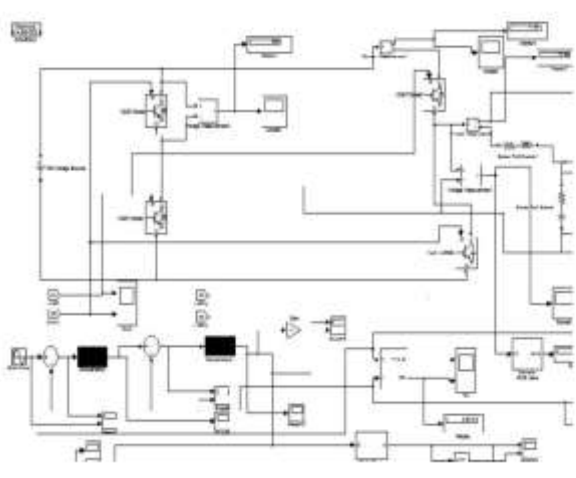

Figure 5 the simulink model of CCC type single-phase inverter with controller

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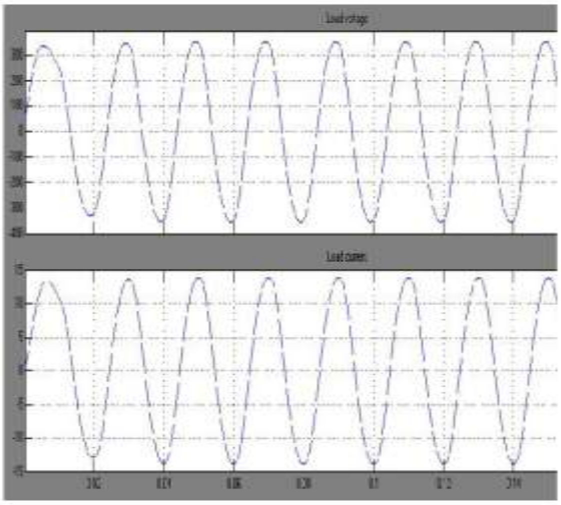

Fig 6 simulation results obtained from 1-phase CCC type inverters without controller

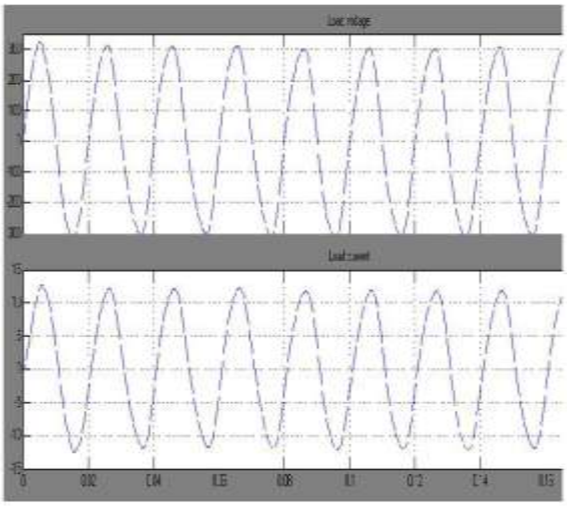

Fig 7 simulation results obtained from 1-phase CCC type inverters with controller

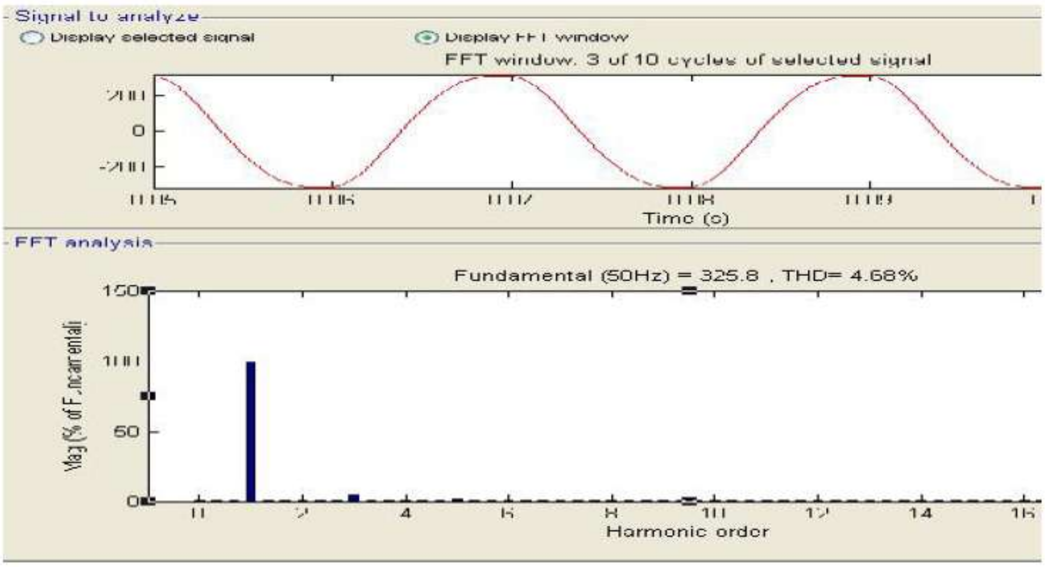

Figure 8

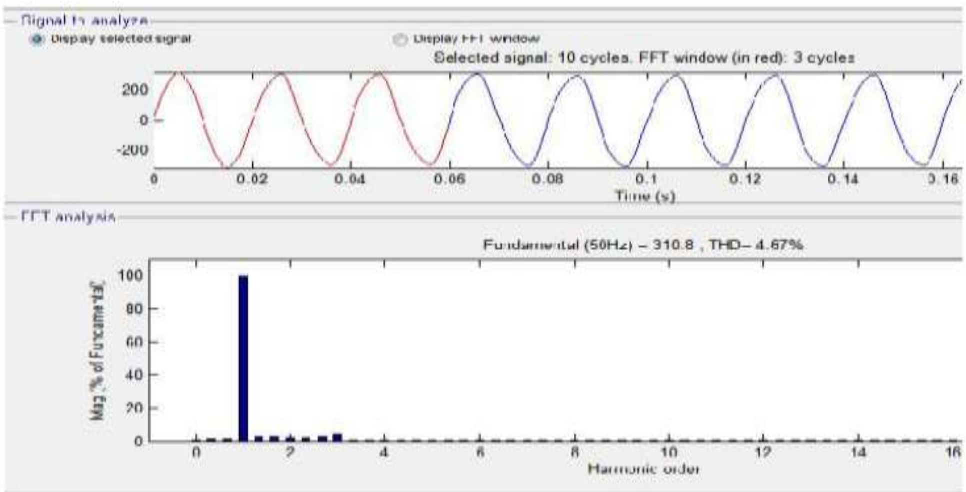

Figure 9

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Figures 6 and 7 show simulation results from single-phase CCC type inverters without & with controllers (open-loop and closed-loop operation), demonstrating that output voltage remains close to the reference in closed-loop & varies dramatically with load change in open-loop for resistive & resistive-inductive loads. Furthermore, findings shown in Figures 8 and 9 concern different THD values acquired, revealing that THD value is reduced with controller, proving better performance of proposed CCC inverter. From Table 1 through Table 4, experimental findings for various load circumstances have been tabulated.

TABLE 1 OPEN - LOOP PERFORMANCE FOR VARIOUS R-LOADS

R-Load in Ω	Vrms in Volts	Irms in Amps	THD in %
25	257	10.2	3.45
30	296	9.8	2.72
35	333	9.5	2.44
40	366	9.12	3.50

TABLE 2 CLOSED - LOOP PERFORMANCE FOR VARIOUS R-LOADS

R-Load in Ω	Vrms in Volts	Irms in Amps	THD in %
25	229	9.19	3.24
30	230.5	7.68	1.62
35	229.8	6.5	1.53
40	230.5	5.76	2.55

TABLE 3 OPEN-LOOP PERFORMANCE FOR VARIOUS R-L LOADS

RL-Load in Ω	Vrms in Volts	Irms in Amps	THD in %
25Ω, 20 mH	245.7	9.40	4.68
25Ω, 30 mH	248	8.6	4.02
30Ω, 20 mH	282.8	9.19	3.08
30Ω, 30 mH	286	7.07	3.33

TABLE 4 CLOSED-LOOP PERFORMANCE FOR VARIOUS R-L LOADS

R L-Load in Ω	Vrms in Volts	Irms in Amps	THD in %
25Ω, 20 mH	230.5	8.83	4.67
25Ω, 30 mH	228.3	8.13	3.07
30Ω, 20 mH	229.8	7.21	2.29
30Ω, 30 mH	229.8	6.56	2.27

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CONCLUSION

MATLAB-Simulink simulation results were used to demonstrate the proposed CCC inverter and control scheme. Unlike a standard PWM inverter, proposed inverter can operate in a closed-loop mode & generates a desired sinusoidal waveform. When turned on & off gently, proposed converter achieves ZCS. The switching frequency, on other hand, is affected by a number of system characteristics such as load demand, LC components, DC voltage magnitude at input side, & so on. The CCC inverter can power a wide range of loads, including those with lagging, leading, or unity power factors. The findings of a single-phase CCC type inverter, both with & without a controller, explain why output voltage in closed-loop remains near to reference & fluctuates dramatically with load change in open-loop for resistive & resistive-inductive loads. The different THD values collected demonstrate that THD value is lowered with the controller, showing that the proposed CCC inverter operates better. Furthermore, suggested inverter is appropriate for UPS applications, dynamic voltage restorers, low-power drives, satellite antennae, & other home appliances that require a pure sine wave to operate efficiently, such as DVD players, vacuum cleaners, emergency lighting, and so on.

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