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"Power Quality improvement using 24 Pulse bridge Rectifier for an isolated Power generation"

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Abstract: This paper deals with the power quality improvement in a conventional electronic load controller (ELC) used for isolated Pico-hydropower generation based on an asynchronous generator (AG). The conventional ELC is based on a six-pulse uncontrolled Diode bridge rectifier with a chopper and an auxiliary load. It causes harmonic currents injection resulting distortion in the current and terminal voltage of the generator. The proposed ELC employs a 24-pulse rectifier with 14 diodes and a chopper. A polygon Wound autotransformer with reduced kilovolts ampere rating For 24-pulse ac–dc converter is designed and developed for harmonic Current reduction to meet the power quality requirements As prescribed by IEEE standard-519. The comparative study of Two topologies, conventional ELC (six-pulse bridge-rectifier-based ELC) and proposed ELC (24-pulse bridge-rectifier-based ELC) is carried out in MATLAB using SIMULINK and Power System Block set toolboxes. Experimental validation is carried out for both ELCs for regulating the voltage and frequency of an isolated AG driven by uncontrolled pico-hydroturbine.

Keywords: Electronic load controller (ELC), isolated asynchronous generator (IAG), pico-hydroturbine, 24-pulse bridge rectifier.

I. INTRODUCTION

The Soaring use of fossil fuels and their depletion over the last two decades combined with a growing concern about pollution of environment have led to a boost for renewable energy generation. This accelerated drive has led to a tremendous progress in the field of renewable energy systems during last decade. It has also resulted in a gradual tapping of the vast mini (100 kW to 1 MW), micro (10–100 kW), and picohydro (less than 10 kW) and wind energy potential available in isolated locations (where grid supply is not accessible). In most of the cases, these generating units have to operate at remote unattended site; therefore, maintenance-free system is desirable. In view of this, the isolated asynchronous generator (IAG) with a simple controller for regulating the voltage and frequency is most prominent option for such applications A number of research publications are available on voltage and frequency controllers for an IAG driven by uncontrolled pico-hydroturbine for single-phase as well three phase power applications. Most of these proposed controllers are reported as electronic load controllers (ELCs) that maintain the constant power at the generator terminal, to regulate constant voltage and frequency. The value of excitation capacitor is selected to generate the rated voltage at desired power. The basic principle of controlling the constant power at the generator terminal is to employ an ELC and operate it in a way so that the total power (absorbed by the load controller and consumer load) is constant. If there is less demand by the consumer, the balance of generated power is absorbed by the ELC.

The energy consumed by the ELC may be utilized for useful work like water heating, space heating, cooking, battery charging, and baking, etc. Various types of ELCs based on controlled (thyristorized) or uncontrolled six-pulse rectifiers with a chopper and an auxiliary load are reported in the literature. These controllers provide effective control but at the cost of distorted voltage and current at the generator terminals, which, in turn, derate the machine. Moreover, the harmonic current injection at generator terminal is not within the prescribed limits by IEEE standards as (6n $\pm$ 1) dominant harmonics are present in such system. These harmonics cause additional losses in the system, resonance, and failure of the capacitor bank. In a phase-controlled thyristor-based ELC, the phase angle of back-to-back-connected thyristors is delayed from 0◦ to 180◦ as the consumer load is changed from zero to full load.

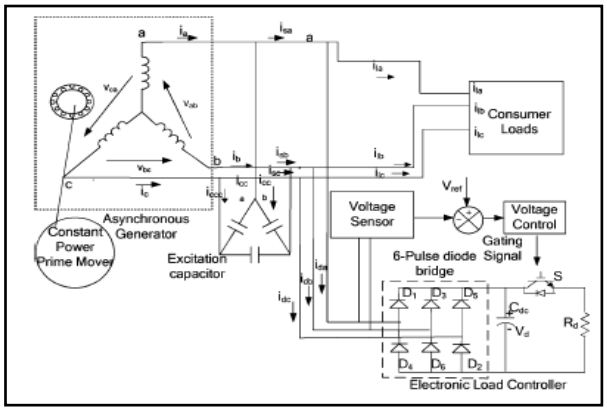

Fig.1 IAG system configuration and control strategy of a chopper switch in a six-pulse diode bridge ELC.

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Due to a delay in firing angle, it demands additional reactive power loading and injects harmonics in the system. In the controlled bridge rectifier type of ELC, a firing angle is changed from 0◦ to 180◦ for single phase and 0◦ to 120◦ for three phases to cover the full range of consumer load from 0% to 100%. In this scheme, six thyristors and their driving circuits are required, and hence, it is complicated, injects harmonics, and demands additional reactive power.

Some of ELCs have been proposed that are having quality of the active filter and employs pulse width modulation (PWM) voltage source converter along with the chopper and auxiliary load at dc link to eliminate the harmonics and provide the functions of voltage and frequency regulation. However, such types of controllers make the system costly and complex with complicated control algorithm and simplicity requirement by the isolated system is lost. Therefore, in this paper, a simple ELC is proposed that regulates the voltage and frequency without any harmonic distortion at the generator terminals. The proposed controller consists of a 24-pulse rectifier, a chopper, and an auxiliary load. In place of six-pulse rectifier, a 24-pulse rectifier-based ELC has negligible harmonic distortion in the generated voltage and current.

II. LITERATURE SURVEY

1. Ambarnath Banerji, Sujit K. Biswas, and Bhim Singh are explained in paper which title is "Voltage and Frequency Controller for An Autonomous Asynchronous Generator" this paper publish with International Journal on Electrical Engineering and Informatics - Volume 6, Number 2, June 2014 they are explained or focused on A battery Energy storage system (BESS) based voltage and frequency controller (VFC), for an Autonomous Asynchronous Generator (ASG) driven by an uncontrolled pico hydro turbine used in constant power mode, is presented in this paper. Excitation of the asynchronous generator with capacitor bank enables it to generate rated voltage at no load. The additional reactive power demand of the ASG on load and that for the load itself is provided by the VFC. The proposed controller has the capability of harmonic reduction, load balancing and load leveling along with voltage and frequency control. The VFC has been realized using an IGBT based current controlled voltage source converter (CC-VSC) having a battery at its DC link. A simple and effective linear control scheme using SPWM control has been used to control the CC-VSC. This control scheme is easier to implement on hardware than the other reported schemes, as it involves only linear PI controllers. The effectiveness of the proposed controller for an autonomous generator is demonstrated by simulation on MATLAB platform.

2. Abdu Samad P K1, C. Ganesh are explained in paper which title is "Control and Energy Monitoring Scheme for a Stand-Alone Wind Energy Conversion System" this paper publish with Power Syst. Res., vol. 69, no. 2/3, pp. 107–114, May 2004 they are explained Present energy need heavily relies on the conventional sources. But the limited availability and steady increase in the price of conventional sources has shifted the focus toward renewable sources of energy. Among the available alternative sources of energy, wind energy is considered to be one of the proven technologies. With a competitive cost for electricity generation, wind energy conversion system (WECS) is nowadays deployed for meeting both grid-connected and stand-alone load demands. However, wind flow by nature is intermittent. In order to ensure continuous power supply, suitable storage technology is used as backup. A storage system such as a battery bank may be used. In this thesis, the sustainability of a hybrid wind energy and battery system is investigated for meeting the requirements of a stand-alone dc load. A charge controller for battery bank based on turbine maximum power point tracking and battery state of charge is developed to ensure controlled charging and discharging of battery. The mechanical safety of the wind energy conversion system is assured by means of pitch control technique. Both the control schemes are integrated and the efficiency is validated by testing it with various load and wind profiles in numerical computation software SCILAB. The SCILAB model is intended to simulate the behavior of wind turbine using synchronous generators and control the wind electrical energy conversion processes. Rotational speed and torque become the controlled variables in wind energy and mechanical energy conversion process. Control scheme has been developed for switching DC-DC buck type converter. It is possible to predict the behavior of the system by simulation using SCILAB-XCOS software. Self-excited induction generator research—a survey

3. G.K. Singh are explained in paper which title is "Self-excited induction generator research—a survey" in this explained the The increasing importance of fuel saving has been responsible for the revival of interest in so-called alternative source of energy. Thus, the drive towards the decentralization of power generation and increasing use of non-conventional energy sources such as wind energy, bio-gas, solar and hydro potential, etc. has become essential to adopt a low cost generating system, which is capable of operating in the remote areas, and in conjunction with the variety of prime movers. With the renewed interest in wind turbines and micro-hydro-generators as an alternative energy source, the induction generators are being considered as an alternative choice to the well-developed synchronous generators because of their lower unit cost, inherent ruggedness, operational and maintenance simplicity

III. SYSTEM DESIGN

a) System Configuration:
Fig. shows the isolated picohydro generating system that consists of an IAG, excitation capacitor, consumer loads, and conventional ELC (six-pulse diode rectifier along with

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the chopper). The diode bridge is used to convert ac terminal voltage of IAG to dc voltage. The output dc voltage has the ripples, which should be filtered, and therefore, a filtering capacitor is used to smoothen the dc voltage. An insulated gate bipolar junction transistor (IGBT) is used as a chopper switch providing the variable dc voltage across the auxiliary load. When the chopper is switched ON, the current flows through its auxiliary load and consumes the difference power (difference of generated power and consumer load power) that results in a constant load on the IAG, and hence, constant voltage and frequency at the varying consumer loads.

The duty cycle of the chopper is varied by an analog-controller-based proportional–integral (PI) regulator.The sensed terminal voltage is compared with reference voltage and error signal is processed through PI controller. The output of PI controller is compared with fixed frequency sawtooth wave to generate the varying duty cycle switching signal for the chopper switch. According to the principle of operation of the system, the suitable value of capacitors is connected to generate rated voltage at desired power [21]. The input power of the IAG is held constant at varying consumer loads. Thus, IAG feeds two loads (consumer load + ELC) in parallel such that the total power is constant

$$P_{gen} = P_{ELC} + P_{load}$$

where Pgen is generated power by the IAG (which should be kept constant), Pload is consumed power by consumers, and PELC is the power absorbed by the ELC.

What is an IGBT?
An IGBT, or insulated gate bipolar transistor, is a solid state device (with no moving parts). It is a switch that is used in order to allow power flow in the On state and to stop power flow when it is in the Off state. An IGBT works by applying voltage to a semiconductor component, therefore changing its properties to block or create an electrical path. IGBT used as a chopper switch Chopper DC to DC converter is very much needed nowadays as many industrial applications are dependent upon DC voltage source.

The performance of these applications will be improved if we use a variable DC supply. It will help to improve controllability of the equipments also. Examples of such applications are subway cars, trolley buses, battery operated vehicles etc. We can control and vary a constant dc voltage with the help of a chopper. Chopper is a basically static power electronics device which converts fixed dc voltage / power to variable DC voltage or power. It is nothing but a high speed switch which connects and disconnects the load from source at a high rate to get variable or chopped voltage at the output.Chopper can increase or decrease the DC voltage level at its opposite side. So, chopper serves the same purpose in DC circuit transfers in case of ac circuit. So it is also known as DC transformer.

b). Proposed 24-Pulse Elc Configuration:
Fig. shows the proposed reduced rating polygon connected autotransformer [22], [23] fed 24-pulse ac–dc-converter-based ELC for an isolated pico-hydropower generation applications. This configuration needs one zero-sequence blocking transformer (ZSBT) to ensure independent operation of the two rectifier bridges. It exhibits high impedance to zero-sequence currents, resulting in 120◦ conduction for each diode and also results in equal current sharing in the output. An interphase reactor tapped suitably to achieve pulse doubling [22]–[24] has been connected at the output of the ZSBT. Two rectifiers output voltages V_{d1} and V_{d2} shown in Fig. 2 are identical but have a phase shift of 30◦ (required for achieving 12-pulse operation), and these voltages contain ripple of six times the source frequency.

The rectifier output voltage Vd is given by

$$V_d = 0.5\,(V_{d1} + V_{d2}). \quad (1)$$

Similarly, the voltage across interphase reactor is given by

$$V_m = V_{d1} - V_{d2} \quad (2)$$

where Vm is an ac voltage ripple of 12 times the source frequency appearing across the tapped interphase reactor, as shown in Fig. 2. This pulse multiplication arrangement [22], [24] for diode bridge rectifiers has been used for desired pulse doubling for line current harmonic reduction.The ZSBT helps in achieving independent operation of the two rectifier bridges, thus eliminating the unwanted conducting sequence of the rectifier diodes. The ZSBT offers very high impedance for zero sequence current components. However, detailed design of the interphase reactor and ZSBT has been given in [22] and the same procedure is used in this paper. To achieve the 12-pulse rectification, the necessary requirement is the generation of two sets of line voltages of equal magnitude that are 30◦ out of phase with respect to each other (either ±15◦ or 0◦ and 30◦).From the generator terminal voltages, two sets of three-phase voltages (phase shifted through +15◦ and −15◦) are produced.

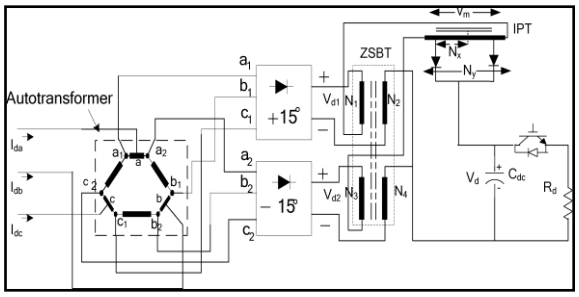

Fig. 2. Proposed 24-pulse ELC for an IAG.

IV. ELECTRONIC LOAD CONTROLLER

The ELC consists of the following modules. The design of each of these modules and their final integration prepares the complete ELC. The following paragraphs include the

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descriptions of each block with the circuit diagrams alongside.

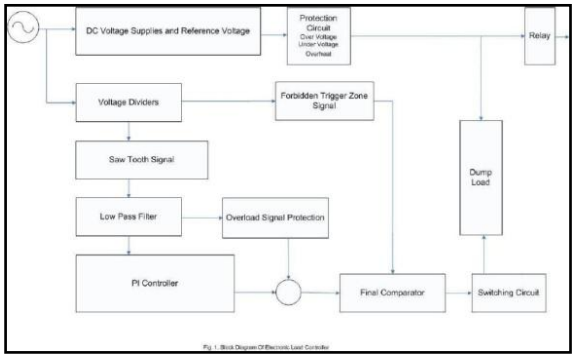

Fig. 10 Electronic Load Controller

DC Voltage Supplies and Reference Voltage Module This module produces supply voltage that power the other modules and the reference voltage that is used by other modules. The input to this module is the generator voltage which is high and variable with large current capacity.

The output of the module is lower, more stable voltage with lower capacity. The 220 V ac voltage of the generator is first stepped down by a transformer to a smaller ac voltage. Using a rectifier the ac voltage is converted to dc voltage which is regulated to give constant output voltage. This module thus provides power to the electronics. Thus the design of this module consists of the design of the suitable transformer, rectifier and the voltage regulator.

The 100R resistor and 100 nf capacitor form an RC filter with a time constant of 0.01ms. It acts as a simple low-pass filter that smoothens very sharp voltage spikes from generator voltage somewhat before this is fed to the transformer and voltage dividers module. Even when there is just the usual noise on generator signal, some power is dissipated in this resistor so it should really be a 1 W type. Voltage over the capacitor can rise very high. So, the 100 nf capacitor is 250V `class X2' capacitor.The fuse protects the transformer against too high currents in case of a short-circuit at the secondary side, or generator voltage being too high while frequency has not increased proportionally. The capacitive current drawn by the capacitor should not pass through the fuse because this would partly annihilate the reactive current drawn by the transformer. Then the transformer could still receive a larger current than the fuse allows and the transformer would not be properly protected. The transformer reduces generator voltage to a level suitable for powering the electronics. The bridge rectifier converts it to a DC voltage that appears on measuring point `Unstable'. Apart from serving as input voltage for the next step, this voltage issued as input signal for `overvoltage' and `under voltage' protection features.Together, the 4k7 and 5k6 resistor, 24 V zener diode, transistor Q1 and 2200 uF elco'sform a coarse stabilized voltage supply with `V24' as output voltage. Besides providing power to the next step, V24 is used to power the coil of the relay. Together with the 470 nf and 100 nF capacitors, the 78L15 stabilized voltage supply produces a nice, stable voltage +15 V that is used to power all electronics .The LM317T voltage regulator produces an accurate, stable voltage `Vref' of approximately 6.9 V that is used as reference voltage at many points in the circuit.

V. MATLAB-BASED MODELING

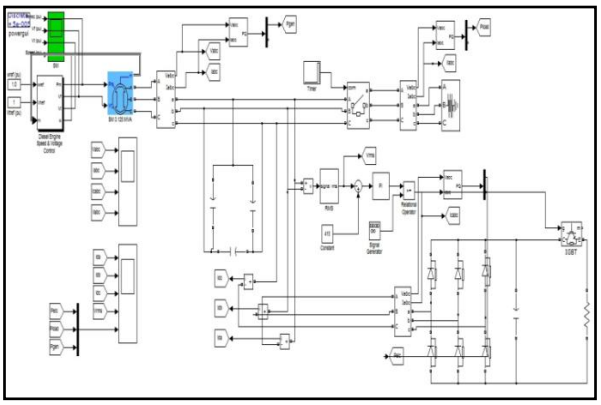

Fig. 3 Simulation diagram of Six-Pulse ELC

A 7.5 kW, 415 V, 50 Hz asynchronous machine is used as an IAG and the ELC is modeled using available power electronics block set like diode bridge rectifier and a chopper with an auxiliary resistive load and multilinking transformers are used to create the desired phase shift for 24-pulse converter operation. Simulation is carried out in MATLAB version of 7.1 at discrete step of 1E−6. Detailed simulation and comparative analysis of both types of ELCs are given in following sections. Figure shows the different transient waveforms of IAG with conventional ELC using six- pulse diode bridge rectifier. The value of the capacitor is selected for generating the rated rms voltage at rated load. Initially, the consumer load is off and the ELC is consuming full power to an auxiliary load. At 2s, a consumer load of around 5 kW is switched ON and it is observed that to control the constant power at generator terminal, the current drawn by ELC is reduced, while on removal of consumer load at 2.3s it is again increased. Because of using six pulse bridge rectifier based ELC, the distortion in the generator voltage and current is observed, and the magnitude and frequency of the generated voltage are controlled.

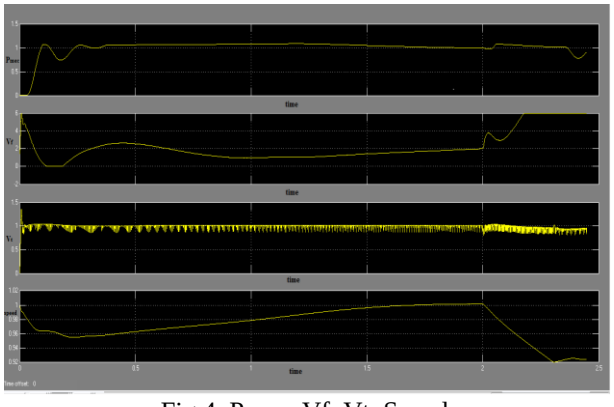

Fig.4. Pmec, Vf, Vt, Speed

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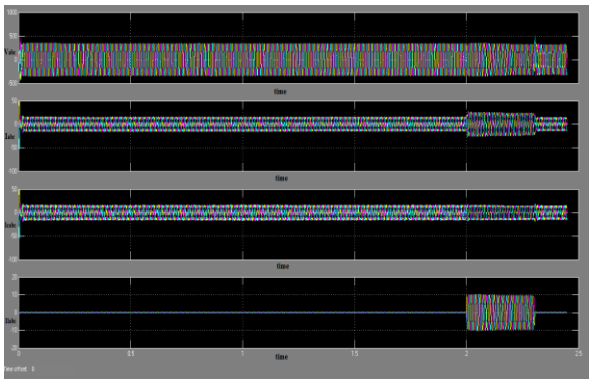

Fig. 5 Vabc, Iabc, Icabc, ILabc

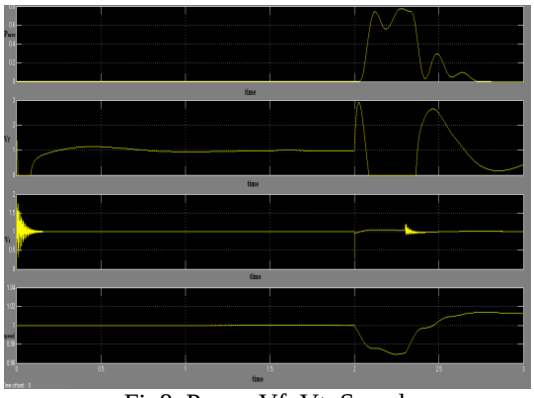

Fig8. Pmec, Vf, Vt, Speed

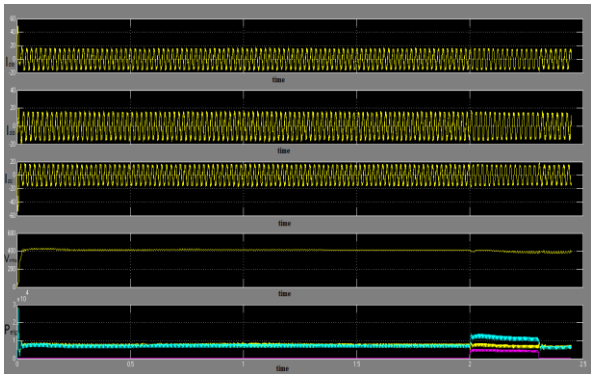

Fig. 6 Ida, Idb, Idc, Vrms, Pelg

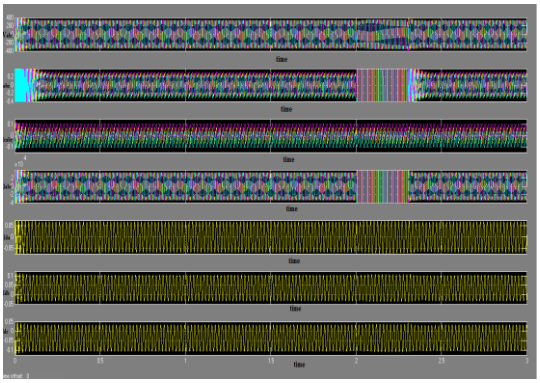

Fig9. Vabc, Iabc,Icabc, Ilabc, Ida,Idb,Idc

CASE: II 24-Pulse ELC

Figure shows the transient waveforms of IAG using 24-pulse rectifier-based ELC. In similar manner of conventional ELC, the proposed ELC controls the constant power at generator terminal with variation of consumer loads. Here, it is observed that the voltage and frequency are maintained at constant value, and at the same time, the distortion in the generator voltage and cur-rent is negligible compared to conventional ELC. Its performance is improved in comparison to conventional ELC and the distortion in voltage and current of the generator is observed almost negligible which is respectively. when conventional ELC draws maximum generated power; here, it is observed that due to nonlinear be-havior of this ELC, it draws the current having total harmonic distortion (THD) which, in turn, distorts the voltage.

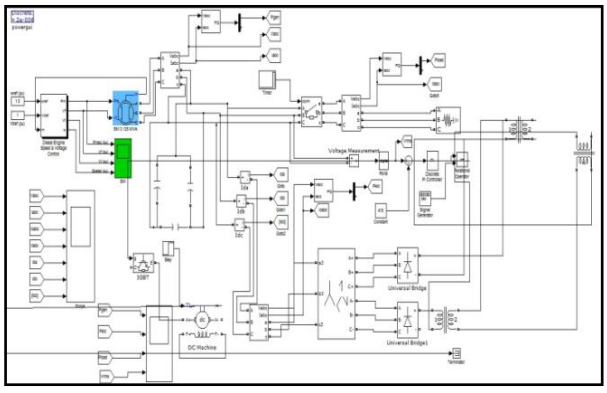

Fig.7 Simulation diagram of 24-Pulse ELC

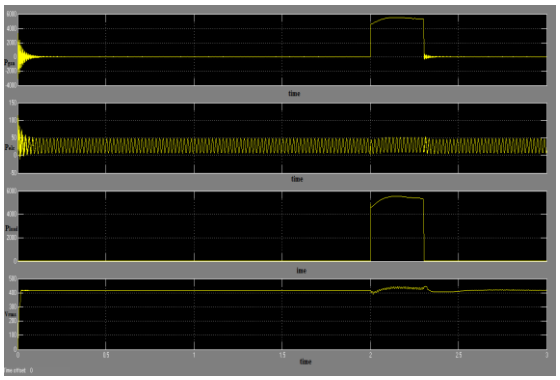

Fig. 10.Pgen, Pelc, Pload, Vrms

Comparison Case I and Case II

With conventional ELC, it is observed that THD of the generated voltage and current is 4.8% and 10.8%, respectively, under the condition of consumer load and removal of the load, the total generated power is absorbed by the ELC and condition becomes more severe because of the nonlinear behaviour of conventional ELC and the observed THD of the voltage and current is 7.8% and 17.8%, respectively, which is shown in Fig. of simulation. With proposed 24-pulse ELC, it is clearly demonstrated that THD of the generated voltage and current is improved and there is negligible distortion in the generated voltage and current. On application of the consumer load, the voltage and current THD is 0.8% and 2.0%, respectively, while under the condition of zero consumer load, when the load controller draws full generated power the THD of the

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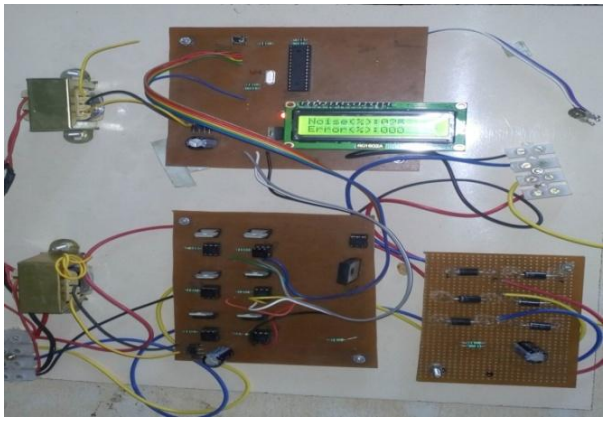
generated voltage and current is around 0.8% and 2.2% that is well within the 5% limit imposed by IEEE- 519 standard and much less than in case of six-pulse diode bridge- based ELC.

VI. RESULTS



Specification of parameters of hardware

Table no.1 Specification parameters of hardware

Sr No.	Components	Specification
1	Supply Voltage	415 V
2	Switching frequency	50 Hz
3	ZSBT	PT+Isolation transformer(1200v,25 A)
4	Switching device	IGBT
5	Resitive DC load	3A,1000V
6	Electrolytic Capacitor	10uF,415v
7	Optocoupler	Isolating test voltage 5000v
8	Output power	7.5 kw
9	8 bit microcontroller	Operating Voltage 1.8 - 5.5V 32 x 8 General Purpose Working Registers Up to 20 MIPS Throughput at 20 MHz On-chip 2-cycle Multiplier

VI. CONCLUSION

The proposed ELC has been realized using 24-pulse converter and a chopper. A comparative study of both types of ELCs (6-pulse and 24-pulse configured ELC) has been demonstrated on the basis of simulation using standard software MATLAB and developing a hardware prototype in the laboratory environment. The proposed 24-pulse ELC has given improved performance of voltage and frequency regulation of IAG with negligible harmonic distortion in the generated voltage and current at varying consumer loads

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