ISSN 2229-5518

Isolated Pico-Hydropower Generation Using Asynchronous Generator for Power Quality Improvement

Mr.K.V.N.S Pavan Kumar, Mrs.E.Praveena, Prof. P.V. Kishore

Abstract - A comparative study between the topologies consisting of the Conventional Electronic Load Controller and the Proposed Electronic Load controller (ELC)has been carried out in this paper for the power Quality Improvement in a conventional Electronic Load controller used for Isolated pico-hydropower generation using Asynchronous generator (AG). A polygon wound autotransformer with reduced KiloVolts ampere rating is employed in the proposed ELC for reducing the harmonic current reduction inorder to meet the power quality requirements as prescribed by IEEE standard-519. The conventional ELC employs six-pulse-bridge-rectifier and the Proposed ELC employs twenty four -pulse-bridge-rectifier. The study is carried out in MATLAB using SIMULINK and power system blockset toolboxes. Experimental validation is carried out for both ELCs for regulating the voltage and frequency of an isolated Asynchronous generator driven by uncontrolled pico-hydroturbine.

Index Terms— Electronic load controller (ELC), isolated asynchronous generator (IAG), pico-hydroturbine, polygon wound autotransformer

1. INTRODUCTION

THe depletion of fossil fuels and the environmental pollution leads to the boost for renewable power generation, comprising of mini, micro and picohydro and wind energy potential available in isolated locations (where grid supply is not accessible) for which maintenance –free system is desirable. In view of this, the isolated asynchronous generator (IAG) with a simple controller for regulating the voltage 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 [5] as well three phase power applications [6]–[14].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 [7]–[14]. 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 [15] 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 [16]. 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 [9], a firing angle is changed from 0. to 180. For single phase and 0. to 120. for three phase 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 [17]–[20] 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. A comparative study based on simulation is presented and it is also verified experimentally for both types of ELCs.

2. SYSTEM CONFIGURATION

Fig. 1 shows the isolated picohydro generating system that consists of an IAG, excitation capacitor, consumer loads, and conventional ELC (six-pulse diode rectifier along with the chopper). The diode bridge is used to convert ac

ISSN 2229-5518

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 consume 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 saw tooth 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

$$P\text{gen} = P\text{ELC} + P\text{load}$$

Where Pgen is generated power by the IAG (which should be kept constant), *P*load is consumed power by consumers, and *P*ELC is the power absorbed by the ELC

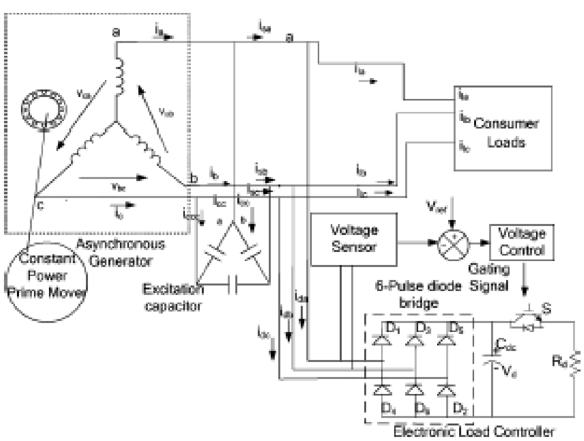


Fig.1. IAG system configuration and control strategy of a chopper switch in a six-pulse diode bridge ELC.

3. PROPOSED 24-PULSE ELC

Fig. 2 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 *V*d is given by

$$V\text{d} = 0.5\,(V\text{d1} + V\text{d2}) \text{ -----. } (1)$$

Similarly, the voltage across interphase reactor is given by

$$V\text{m} = V\text{d1} -- V\text{d2} \quad \text{---------------} \ (2)$$

where *V*m 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 +150 and -150) are produced. The number of turns or voltage fraction across each winding of the autotransformer required for +15. and -15. phase shift is calculated by referring Fig.3 as follows:

$$\text{VNS1} = \text{VNS2}. \text{ ---------- } (3)$$

Applying "Sine" rule in triangle "a1 oa2" [22], [23]

$$\frac{V_{A1}}{\sin 90^\circ} = \frac{V_{NS1}}{\sin 15^\circ} = \frac{V_A}{\sin 75^\circ} \qquad (4)$$

$$V_{NS1} = \frac{\sin 15^\circ}{\sin 75^\circ} V_A$$

$$V_{NS1} = 0.2679\, V_A = 0.2679 \left(\frac{V_{ca}}{\sqrt{3}}\right) \qquad (5)$$

$$V_{A1} = \frac{\sin 90^\circ}{\sin 75^\circ} V_A$$

$$V_{A1} = 1.0352\, V_A = 1.0352 \left(\frac{V_{ca}}{\sqrt{3}}\right) \qquad (6)$$

$$V_{NLL} = \frac{\sin 90^\circ}{\sin 45^\circ} V_{A1}$$

$$V_{NLL} = 1.4639\, V_A = 1.4639 \left(\frac{V_{ca}}{\sqrt{3}}\right) \qquad (7)$$

ISSN 2229-5518

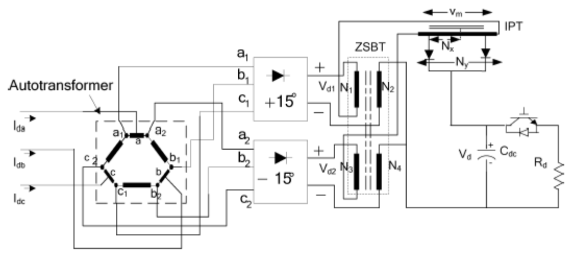


Fig.2. Proposed 24-Pulse ELC for an IAG

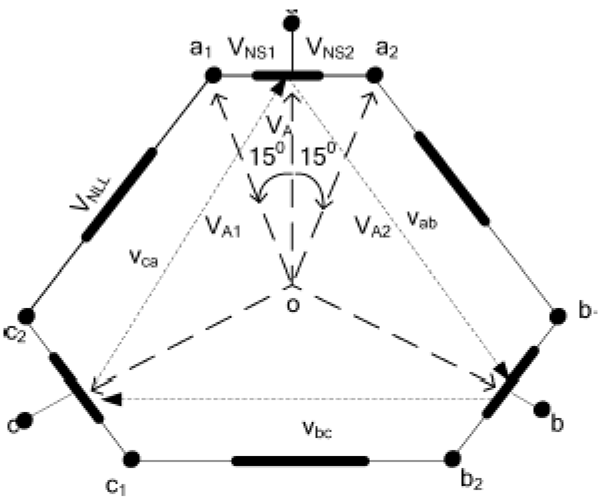


Fig.3. Phasor and winding diagram of proposed 24-Pulse autotransformer arrangement for 24-pulse ac-dc converter for proposed ELC

where *V*ca is the line voltage of 415V. The terms *V*NS1 and *V*NS2 are the voltage induced across the short winding and *V*NLL is the induced voltage across the long winding of polygon connected autotransformer. Detailed hardware design of polygon connected autotransformer, ZSBT, and interphase transformer (IPT) are given in the Appendix along with the complete design of the proposed 24-pulse ELC.

4. MATLAB BASED MODELING

A 7.5 kW, 415 V, 50 Hz asynchronous machine is used as an IAG and the ELC is modeled using available power electronics blockset like diode bridge rectifier and a chopper with an auxiliary resistive load and multi winding 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.

5. SIMULATION STUDY

Here, transient waveforms of the generator voltage (*v*abc), generator current (*i*abc), capacitor currents (*i*cabc), consumer load current (*i*labc), ELC current (*i*da, *i*db, *i*dc), rms value of the generated voltage (*v*rms), frequency (*f*), speed of the generator (*w*g), variation in the load power (*P*load), ELC power (*P*ELC), and generated power (*P*gen) are given under the sudden application and removal of the consumer loads for both types of ELCs in Figs. 4 and 5, respectively, while harmonic spectra of load current, generator voltage, and current are demonstrated in Figs. 6 and 7 for both types of ELCs.

5.1. Performance of an conventional six-Pulse ELC

Fig. 4 shows the different transient waveforms of IAG with conventional ELC using six-pulse diode bridge rectifier. Here, the value of the capacitor is selected for generating the rated rms voltage (415 V) at rated load (7.5 kW). Initially, the consumer load is OFF and the ELC is consuming full 7.5 kW power to an auxiliary load. At 2 s, a consumer load of around 5 kW is switched ON and it is observed that to control the constant power at the generator terminal, the current drawn by ELC is reduced, while on removal of consumer load at 2.3 s, 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. Similar dynamics are performed in case of proposed 24-pulse ELC and demonstrated in Fig. 5 and discussed in following section in detail. Fig. 6 shows the harmonic spectra under zero load condition when conventional ELC draws maximum generated power; here, it is observed that due to nonlinear behavior of this ELC, it draws the current having total harmonic distortion (THD) of 37.13% which, in turn, distorts the voltage (THD of 8.3%) and current (THD of 11.33%) at the generator terminal.

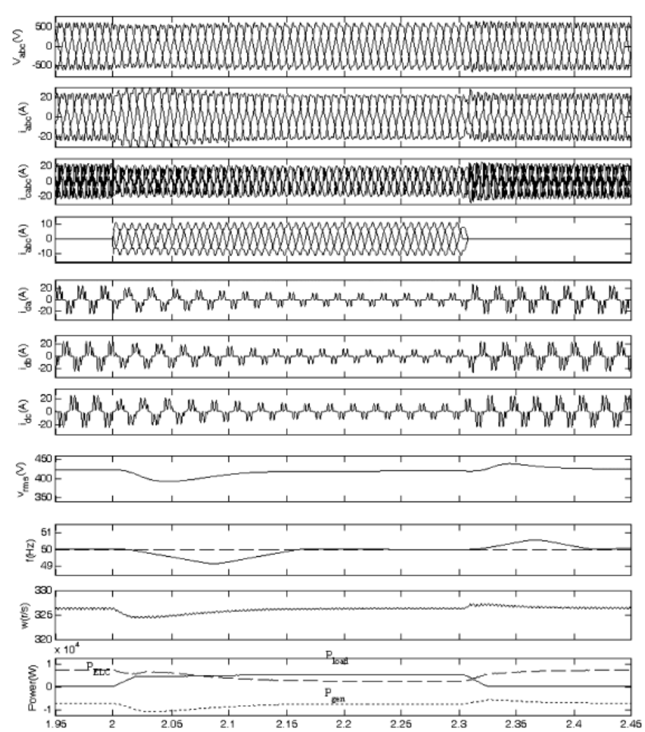


Fig.4. Simulated transient waveforms of IAG on application and removal of consumer load using six-Pulse diode bridge rectifier based ELC

5.2. Performance of Proposed 24-pulse ELC

Fig. 5 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 current is negligible compared to conventional ELC. Fig. 7 shows the harmonic spectra of the ELC current, generator voltage, and generator current, which shows that because of 24-pulse operation of an 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 0.42% and 0.47%, respectively.

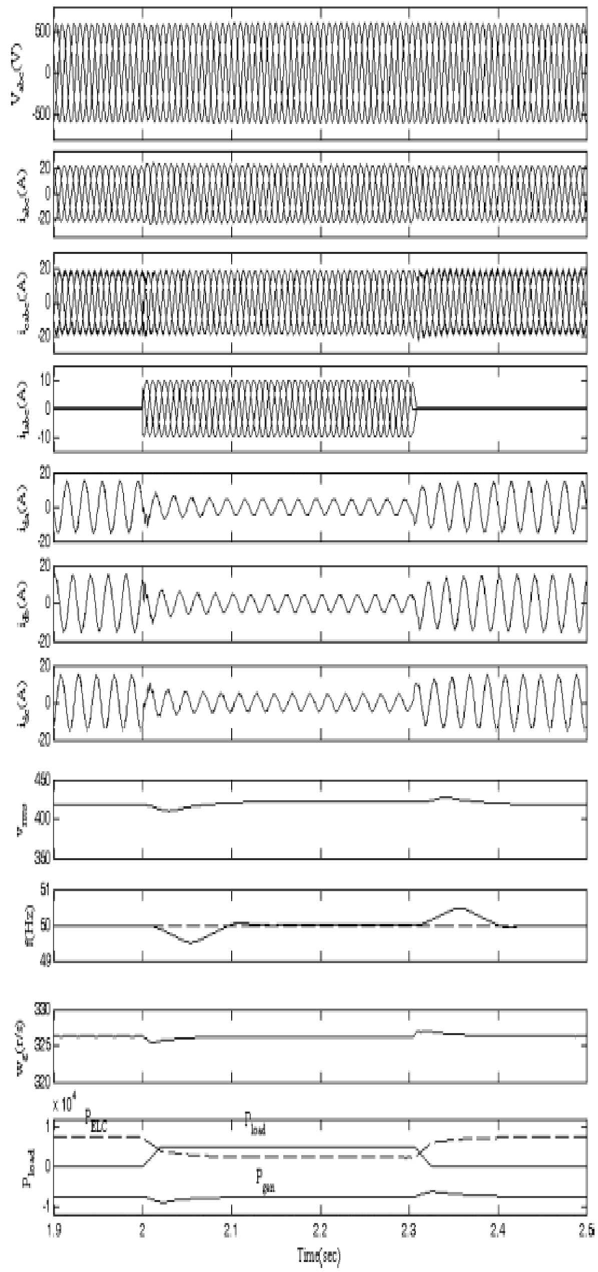


Fig.5. Simulated transient waveforms of IAG on application and removal of consumer load using 24-Pulse rectifier based ELC

6. EXPERIMENTAL INVESTIGATION

In the experimental investigation, sensed terminal voltage of IAG is compared with reference voltage and error signal is fed to the PI controller. The proportional and integral gains of the PI controller can be varied externally by means of having potentiometers. The output of the PI controller is compared with the saw tooth carrier waveform. Frequency and magnitude of the saw tooth waveform are decided by the externally connected resistive and capacitive elements. The PI controller and PWM generator are available in a single chip IC-3525. The output stage of the PWM controller has two push–pull amplifiers, which gives two outputs, one with a duty cycle variation of 0–45% and the second with duty cycle variation of 50–95%. For the chopper application, only a single output is needed with the duty cycle varying in the maximum possible range. Using the IC-3525, this is achieved by paralleling the two outputs so that the duty cycle variation can be achieved. The chopper has to be kept OFF when the IAG is building up voltage and also when it is fully loaded with the consumer load. But the IC-3525 gives an output pulse of duty cycle 10% even when the feedback signal is less than the reference value. So, the PWM controller output is logically ANDed (IC-HD14081B) with another signal given as "pulse block/release" signal.

Figs. 8 and 9 demonstrate the experimental performance of conventional ELC and proposed ELC under the transient conditions of load variations, respectively. Here, transient

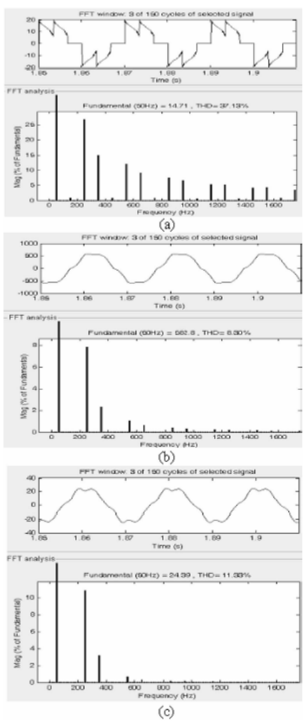


figure: 6

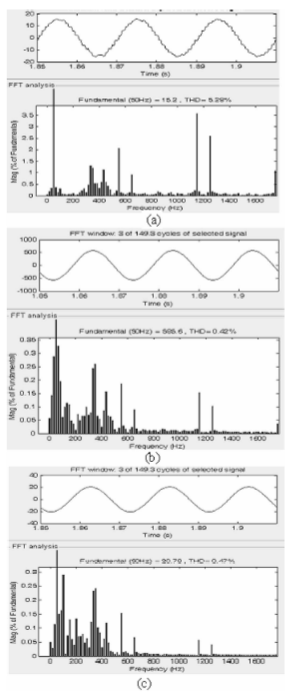


figure: 7

Fig.6. Waveforms and harmonic spectra of (a) conventional six-pulse ELC current (ida), (b) generator voltage (va), and (c) generator current (ia) under the zero consumer load conditions

Fig.7. Waveforms and harmonic spectra of (a) proposed 24-pulse ELC current (ida), (b) generator voltage (va), and (c) generator current (ia) under the zero consumer load conditions

waveforms of the generator voltage (*v*a), generator current (*i*a), consumer load current (*i*la), and ELC current (*i*da) are captured using Agillent-4 channel storage oscilloscope. For experimentation, the value of excitation capacitor is selected to generate 230 V at generated power of 3.5 kW.

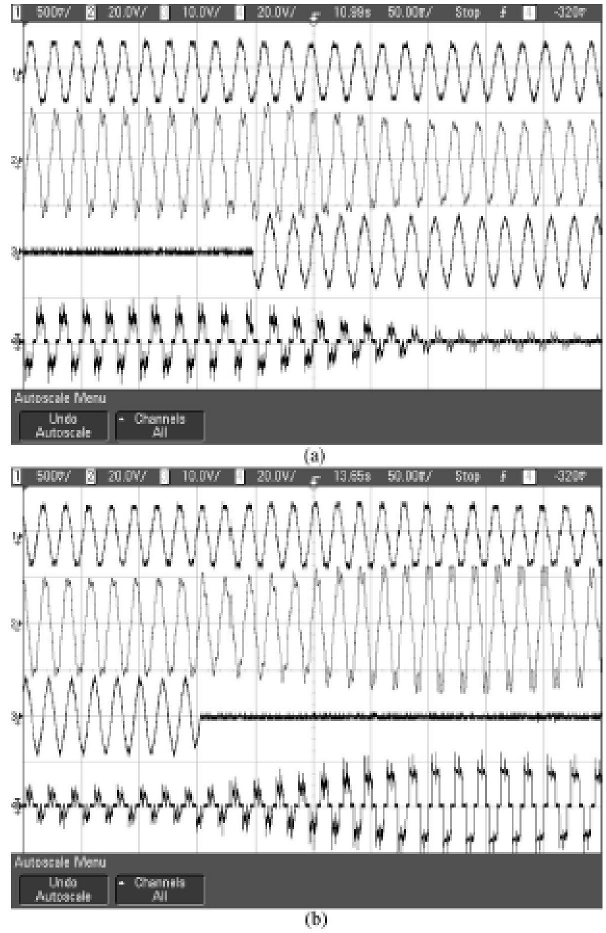


Fig. 8. Experimental transient waveforms of (1) generator voltage (v_a) (2) generator current (i_a) (3) consumer load current (i_{la}) and (4) ELC current (i_{da}) on application and removal of consumer load using six-pulse diode-bridge-rectifier-based ELC. Scale: ch1–1div = 1000 V, ch2–1div = 20 A, ch3–1div = 10 A, ch4–1div = 20 A. (a) Load application. (b) Load removal.

6.1. Performance of conventional six-pulse ELC

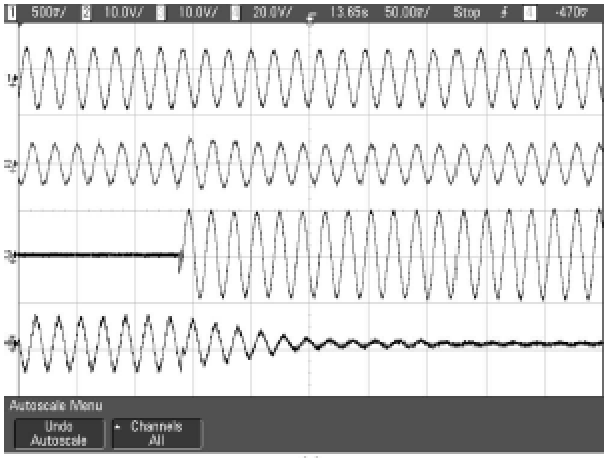
Fig. 8(a) and (b) shows the performance of IAG with the conventional ELC at sudden application and removal of the consumer load, respectively. Here, it is clearly demonstrated that when the consumer load is applied, the controller responds and current flowing through ELC is reduced to control total generated power at the generator terminal constant. Availability of the sufficient excitation capacitor keeps the constant voltage at the generator terminal. Here, an observation is made that because of the nonlinear behavior of ELC due to six-pulse diode rectifier, the generator voltage and current are badly distorted, and when there is zero consumer load, situation becomes more severe.

6.2. Performance of Proposed 24-pulse ELC

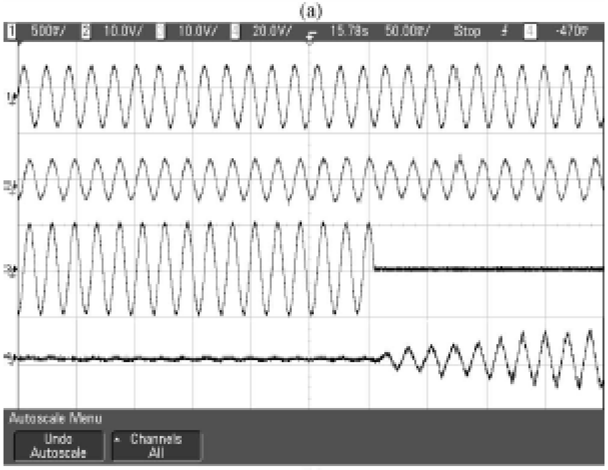
Fig. 9(a) and (b) shows the performance of IAG with the proposed 24-pulse rectifier-based ELC at application and removal of consumer loads. In similar manner of the conventional ELC, the proposed ELC has maintained the

ISSN 2229-5518

constant power at the generator terminals to regulate the magnitude and frequency of the generated voltage. Here, an observation is made that in comparison to the conventional ELC, the proposed ELC has regulated constant power without distorting the generated voltage and current.



(a)



(b)

Fig. 9. Experimental transient waveforms of (1) generator voltage (v_a), (2) generator current (i_a) (3) consumer load current (i_{La}), and (4) ELC current (i_{da}) on application and removal of consumer load using 24-pulse rectifier-based ELC. Scale: ch1−1div = 1000 V, ch2−1div = 20 A, ch3−1div = 10 A, ch4−1div = 20 A. (a) Load application. (b) Load removal.

6.3. comparative study of power quality aspects

Figs. 10 and 11 demonstrate the waveform and harmonic spectra of the generator voltage (va) and current (ia) for conventional ELC and proposed ELC, respectively, under the condition of load application and zero consumer load. Fluke 43B power analyzer is used to measure the THD of the terminal voltage and the generator current.

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 as shown in Fig. 10(i). On removal of the load, the total generated power is absorbed by the ELC and condition becomes more severe because of the nonlinear behavior of conventional ELC and the observed THD of the voltage and current is 7.8% and 17.8%, respectively, which is shown in Fig. 10(ii).

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, as shown in Fig. 11(i), while under the condition of zero consumer load, when the load controller draws full generated power the THD of the generated voltage and current is around 0.8% and 2.2%, as demonstrated in Fig. 11(ii) that is well within the 5% limit imposed by IEEE- 519 standard [15] and much less than in case of six-pulse diode bridge- based ELC.

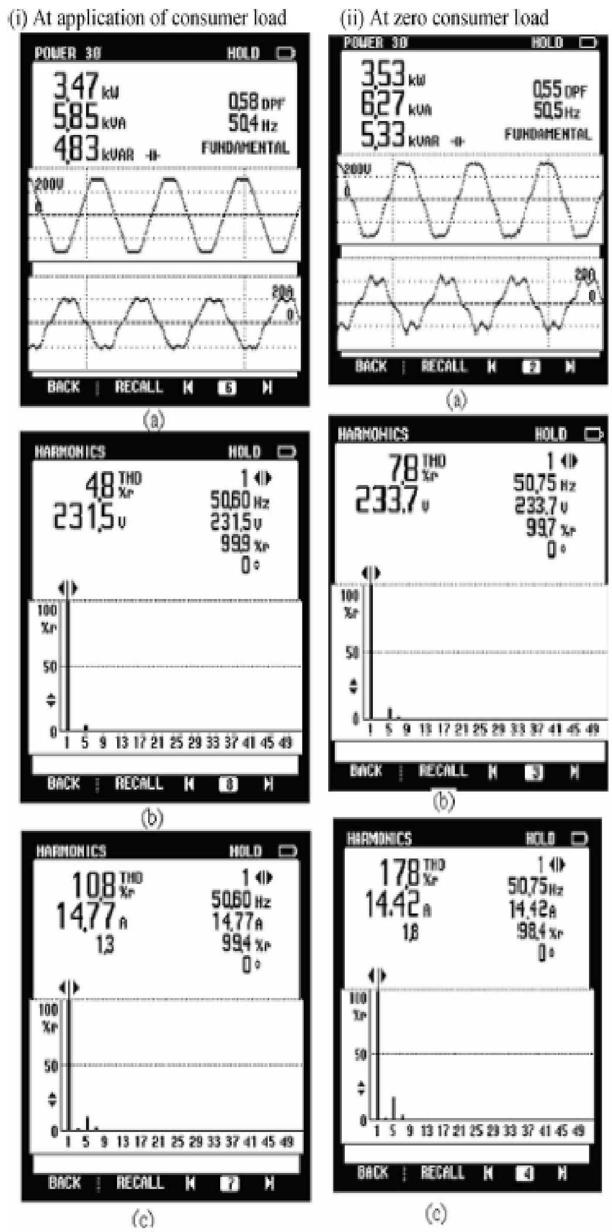


Fig. 10. Waveforms and harmonic spectra of generator voltage and current under condition of (i) load application and (ii) at zero consumer load for conventional six-pulse ELC.

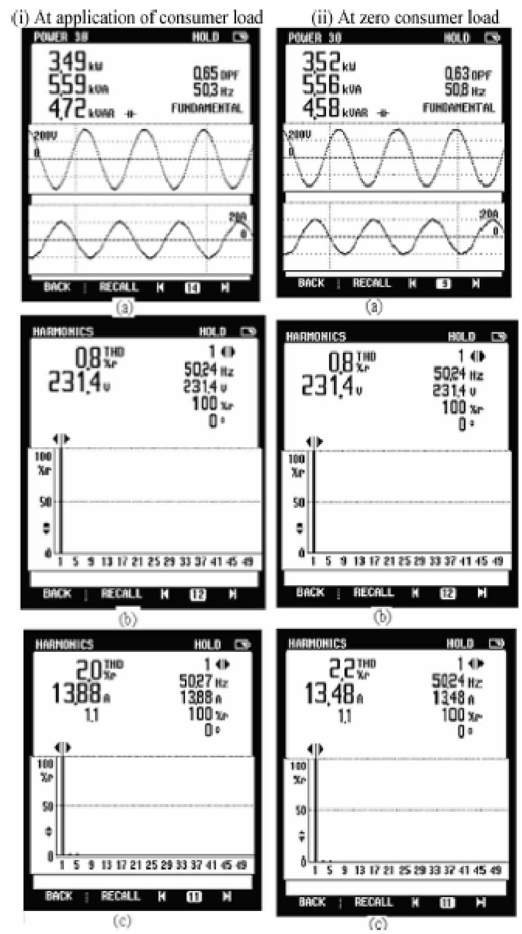


Fig. 11. Waveforms and harmonic spectra of generator voltage and current under condition of (i) load application and (ii) at zero consumer load for a proposed 24-pulse ELC.

7. CONCLUSION

Since the conventional ELC has high total Harmonic Distortion for the generated voltage and current under any load conditions and it is severe in case of zero consumer load condition due to the non linear behavior of ELC due to presence of six-pulse diode Rectifier. With the proposed ELC the total harmonic distortion for the generated voltage and current is low by maintaining constant power thus by improving the regulation of the IAG and thus improving the Power Quality in case of both balanced and unbalanced loads. 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.

8. APPENDIX

8.1. parameter determination for Autowound Polygon Transformer

Line voltage of 415 V can be calculated by (5) and (7)
Va1-c2 = VNLL = 350.758 V; TNLL = 579 Turns
Va-a1 = VNS1 = 64.159 V; TNS1 = TNS2 = 106 Turns.
Three single-phase autotransformers have been designed and wound in the laboratory as per the design details:
flux density = 0.8 T, current density = 2.3 A/mm2 , core size = 8, area of cross section of core = 32.25 cm2 (5.08 cm × 6.35 cm). E-Laminations: length = 18.41 cm, width = 17.14 cm, I-lamination: length = 17.14 cm, width = 5.08 cm.

8.2. Design of ZSBT Pulse multiplication [24]

$N1 = N2 = N3 = N4 = 105$ Turns.

8.3. Design of IPT 24- Pulse AC-DC converter[24]

$Nx / Ny = 0.2543$

$Nx = 17$ Turns and $Ny = 67$ Turns.
Using these design parameters, a prototype is developed in the laboratory.

8.4. Design of proposed 24- Pulse ELC

In this controller, the value of an auxiliary load resistance (*R*d) is estimated using absorbed power and voltage across it. If the controller is designed for rated power of the generator, then the value of auxiliary load resistance can be calculated as

$$Rd = (Vd)^2 / Pgen$$

where *P*gen is the rated power of an asynchronous generator (AG) and *V*d is defined as average voltage at dc bus for 24- pulse [24]–[26] diode-rectifier-based ELC

$$Vd = 1.398\, Vll$$

where *V*ll is input line rms voltage at ELC terminals. An overvoltage of *y*% of the rated voltage is considered for the transient conditions, then the peak ac voltage as [25], [26]

$$Vpeak = (\sqrt{2})V11\ \{1+(y/100)\}$$

The current rating of an uncontrolled rectifier and the chopper switch is decided by the active component of an input ac current and calculated as

$$IA = Pgen / \sqrt{3}\, Vll$$

.
In 24-pulse diode rectifier of an ELC, the distortion factor is 0.985; then, input ac current of the ELC may be obtained as [24]

$$IDA = IA / 0.985$$

The crest factor (CF) of the ac current drawn by uncontrolled rectifier with capacitive filter varies from 1.41 to 2.0; hence; the ac input peak current may be calculated as

$$Ipeak = 2\ IDA.$$

TABLE I
COMPONENT RATING OF 24-PULSE UNCONTROLLED-RECTIFIER-BASED ELC

	V_{db} (V)	I_{db} (A)	V_{ch} (V)	I_{ch} (A)	(R_d) (Ω)	C_{dc} (μF)
Calculated	645	21.85	645	21.85	44.88	140
Selected	700	25	1200	25	35	300

The value of dc link capacitance (C_{dc})and ripple factor (μ) for three-phase 24-pulse uncontrolled rectifier is [24], [25]

$$Cdc = \{(1/48fR_{d2})\}\ \{1+ (1/\sqrt{2}\ \mu)\}$$

From these aforementioned equations, voltage and current rating of uncontrolled rectifier (*V*db, *I*db), chopper switch (IGBT) (*V*ch, *I*ch), and filter capacitor (*C*dc) have been calculated by considering an overvoltage of 10% and ripple factor (μ) of 5%. Table I demonstrates the calculated and selected value of proposed 24-pulse rectifier-based ELC for a 7.5 kW, 415 V, star-connected AG.

8.5. Parameters of 7.5Kw,415V,50Hz,Y-connected 4-pole Asynchronous Machine

*R*s = 1 ., *R*r = 0.77 ., *X*lr = *X*ls = 1.5 .,
J = 0.1384 kg·m2
*L*m = 0.134 *H*(*Im* < 3.16)
*L*m = 9e - 5*Im*2 - 0.0087*Im* + 0.1643(3.16 < *Im* < 12.72)
*L*m = 0.068 *H*(*Im* > 12.72).

9. REFERENCES

[1] B. Singh, "Induction generator—A prospective," Electr. Mach. Power Syst., vol. 23, pp. 163–177, 1995.
[2] R. C. Bansal, T. S. Bhatti, and D. P. Kothari, "Bibliography on the application of induction generator in non conventional energy systems," IEEE Trans. Energy Convers., vol. EC-18, no. 3, pp. 433–439, Sep. 2003.
[3] G. K. Singh, "Self-excited induction generator research—A survey," Electr. Power Syst. Res., vol. 69, no. 2/3, pp. 107–114, May 2004.
[4] R. C. Bansal, "Three phase isolated asynchronous generators: An overview," IEEE Trans. Energy Convers., vol. 20, no. 2, pp. 292–299, Jun. 2005.
[5] O. Ojo, O. Omozusi, and A. A. Jimoh, "The operation of an inverter assisted single phase induction generator,"

IEEE Trans. Ind. Electron., vol. 47, no. 3, pp. 632–640, Jun. 2000.
[6] J. M. Elder, J. T. Boys, and J. L. Woodward, "Integral cycle control of stand-alone generators," Proc. Inst. Electr. Eng., vol. 132, no. 2, pp. 57–66, Mar. 1985.
[7] D. Henderson, "An advanced electronic load governor for control of micro hydroelectric generation," IEEE Trans. Energy Convers., vol. 13, no. 3, pp. 300–304, Sep. 1998.
[8] N. P. A. Smith, "Induction generators for stand-alone micro-hydro systems," in Proc. IEEE Int. Conf. Power Electron. Drive Energy Syst. Ind. Growth. New Delhi, India, 1996, pp. 669–673.
[9] R. Bonert and S. Rajakaruna, "Self-excited induction generator with excellent voltage and frequency control," Proc. Inst. Electr. Eng. Gener. Transm. Distrib., vol. 145, no. 1, pp. 33–39, Jan. 1998
[10] B. Singh, S. S. Murthy, and Sushma Gupta, "Analysis and implementation of an electronic load controller for a isolated asynchronous generator," Proc. Inst. Electr. Eng. Gener. Transm. Distrib., vol. 151, no. 1, pp. 51–60, Jan. 2004.
[11] S. S. Murthy, B. Singh, S. Gupta, A. kulkarni, and R. Sivarajan, "Water, Water. . .. Anywhere field experience on a novel pico hydro system to supply power to a remote locations," IEEE Ind. Appl.Mag., vol. 12, no. 4, pp. 65–76, Jul./Aug. 2006.
[12] E. Suarez and G. Bortolotto, "Voltage—Frequency control of a isolated asynchronous generator," IEEE Trans. Energy Convers., vol. 14, no. 3, pp. 394–401, Sep. 1999.
[13] B. Singh, S. S. Murthy, and S. Gupta, "Transient analysis of isolated asynchronous generator with electronic load controller supplying static and dynamic loads," IEEE Trans. Ind. Appl., vol. 41, no. 5, pp. 1194– 1204, Sep. 2005.
[14] J. M. Ramirez and M. E. Torres, "An electronic load controller for self excited induction generators," in Proc. IEEE PES General Meeting. Tampa, FL, Jun. 24–28, 2007, pp. 1–8.
[15] IEEE Guide for Harmonic Control and Reactive Compensation of Static Power Converters, IEEE Standard 519-1992.
[16] L. A. C. Lopes and R. G. Almeida, "Wind-driven induction generator with voltage and frequency regulated by a reduced rating voltage source inverter," IEEE Trans. Energy Convers., vol. 21, no. 2, pp. 297–304, Jun. 2006.
[17] R. S. Bhatia, D. K. Jain, B. Singh, and S. P. Jain, "Battery energy storage system for power conditioning," in Proc. Nat. Power Syst. Conf. NPSC- 2004, pp. 86–91.
[18] B. Singh, S. S. Murthy, and S. Gupta, "A voltage and frequency controller for self-excited induction generators," Electr. Power Compon. Syst., vol. 34, pp. 141–157, 2006.
[19] E. G. Marra and J. A. Pomilo, "Induction-gene rator-based system providing regulated voltage with constant frequency," IEEE Trans. Ind. Electron., vol. 47, no. 4, pp. 908–914, Aug. 2000.
[20] E. G. Marra and J.A. Pomilio, "Isolated asynchronous generator controlled by a VS-PWM bi-directional converter for rural application," IEEE Trans. Ind. Appl., vol. 35, no. 4, pp. 877–883, Jul./Aug. 1999.
[21] B. Singh, S. S. Murthy, and S. Gupta, "STATCOM based voltage regulator for isolated asynchronous generator feeding non-linear loads," IEEE Trans. Ind. Electron., vol. 53, no. 5, pp. 1437–1452, Oct. 2006.
[22] Derek A. Paice, Power Electronic Converter Harmonics—Multipulse Methods for Clean Power. New York: IEEE Press, 1996.
[23] B.Wu, High Power Converters and AC Drives. NewYork: Wiley/IEEE Press, Mar. 2006.
[24] B. Singh, G. Bhuvaneswari, V. Garg, and S. Gairola, "Pulse multiplication in AC–DC converters for harmonic mitigation in vector-controlled induction motor drive," IEEE Trans. Energy Convers., vol. 21, no. 2, pp. 342–352, Jun. 2006.
[25] N. Mohan, T. M. Undeland, and W. P. Robbins, Power Electronics: Converters, Applications and Design, 3rd ed. Singapore: Willey, 2004.
[26] M. H. Rashid, Power Electronics, Circuits, Devices and Applications, 3rd ed. Singapore: Pearson/Prentice-Hall, 2004.

10. BIOGRAPHIES

Mr. P.V. Kishore has obtained his B.Tech Degree from S.V.University, India and M.Tech degree from S.V. University in 2003. He has 12 years of teaching experience and presently a research scholoar at Satyabhama University in the area of power quality improvement using DSTATCOM. Presently he is working Professor and Head of the department in Mother Teresa Institute of Science & Technology, sanketika nagar, sathupally-507303

Mrs.E.Praveena was born in 1980 and obtained her B.Tech Degree from NBKRIST, SV University India and M.Tech degree in the area of Computer Aided Power Systems from NBKRIST, SV University. She has 7 years of teaching experience and presented papers at National Level Conference Held at Saurashtra University, Rajkot. Presently she is working as Assistant Professor in Mother Teresa Institute of Science & Technology, sanketika nagar, sathupally-507303

Mr .K.V.N.S Pavan Kumar was born in 1983 and completed his graduation from TVSCE, Kakatiya University in 2005. He participated and presented papers in national level conferences .Presently he is Pursuing M.Tech in the specialization of Power Electronics & Electric Drives in Mother Teresa Institute of Science & Technology, sanketika nagar, sathupally-507303