Control Theory and Informatics www.iiste.org
ISSN 2224-5774 (Paper) ISSN 2225-0492 (Online)
Vol.6, No.3, 2016

Implementation of Neural Network Based Least Mean Square Algorithm with PID-VPI Controller and Integrated Electronic Load Controller for Isolated Asynchronous Small Hydro Generation

Dipesh Kumar Karmakar[1*] N.G.S Raju[2]
1.M.Tech Student, EEE Department, GITAM University,Visakhapatnam, Andhra Pradesh-530045, INDIA
2.Assistant Professor, EEE Department, GITAM University,Visakhapatnam, Andhra Pradesh-530045, INDIA

Abstract
The Hydro power is recognized as the promising and widely used renewable source of energy for power generation in large scale, it is gaining popularity due to rising rate of depletion as well as increasing cost of fossil fuels. The Hydro power is very economical in case of run-of-the-river scheme, and environmental friendly keeping in mind the harmful effect of fossil fuels on the climate change. This paper deals with neural network (NN) based least mean square (LMS) algorithm known as adaptive linear element (ADALINE) algorithm, with PID-VPI controller for isolated asynchronous generator (IAG) with integrated electronic load controller (IELC) in small hydro generation feeding three-phase four-wire nonlinear load with neutral-current compensation. The integrated electronic load controller (IELC) is based on zigzag/three single-phase transformers and a six-leg insulated-gate bipolar-transistor-based current-controlled voltage-source converter, a chopper switch, and an auxiliary load on its dc bus. The integrated electronic load controller (IELC) utilizes Adaptive linear element (Adaline) to extract the positive-sequence fundamental-frequency component of load current to obtain load balancing in integrated manner and to control the voltage and frequency of the isolated asynchronous generator (IAG). Non-linear loads are considered for critical evaluation of system, as they have the capability to introduce harmonics that are deleterious for any system. The propound system is modeled and simulated in MATLAB environment to demonstrate the effectiveness of the proposed integrated electronic load controller for the control of isolated asynchronous generator.
Keywords:Neural Network (NN), Least Mean Square (LMS), Adaptive Linear Element (ADALINE) Proportional integral derivative controller (PID), Vector proportional integral controller (VPI), integrated electronic load controller (IELC), isolated asynchronous generator (IAG), small hydro generation, voltage-source converter (VSC), voltage and frequency control.

I. Introduction

In present energy crisis situation, renewable energy becomes the best choice of energy as it has surpassed potential for meeting the future energy and development needs. Renewable energy is economic in energy markets and its rapid growth with necessity has made the energy market diverse. Small hydropower, has large potential and low installation cost. It is globally being adopted and considered most appropriate for providing electric power services to remote areas which are unlikely to be served by grid electricity. Renewable energy resources is given priority because: 1) the overwhelming scientific evidence that anthropological emissions of greenhouse gases from carbon combustion threaten catastrophic results from rapid climate change; 2) the severe health and environmental consequences from fossil fuel combustion being experienced in every developed country city; and 3) the high cost, environmental damages and security threats of nuclear power.

Electrical energy from renewable source is an environmental friendly solution for the rapid increasing pollution problems due to excessive use of fossil fuels and growing demand of electrical energy. Incorporating such method of power is inevitable due to the depletion of natural resources. This paper propounds an Integrated Electronic Load Controller to regulate voltage and frequency for an Isolated Asynchronous Generator driven by a constant power small hydro uncontrolled turbine feeding three-phase four-wire nonlinear load [4]-[6]. The neural-network based least mean square algorithm known as Adaptive linear element (adaline) [12]-[14], extracts the positive sequence fundamental component of load current to control the voltage and frequency of an isolated asynchronous generator with load balancing in an integrated manner [15]-[17]. Asynchronous generator is most preferable as it inherits the following qualities: low cost, ruggedness, brushless rotor construction with least maintenance and no requirement of DC supply. The value of the capacitor bank, to supply reactive power to the asynchronous generator is so selected such that it will produce rated voltage at no-load at rated speed [7]. In this type of control strategy, DC bus voltage of voltage source converter of the integrated electronic load controller is less sensitive to load perturbation [8] and is used to control the active power (indirectly, to control the frequency) and reactive power (to control the terminal voltage) of the isolated asynchronous generator. The non-linear loads may introduce problems such as high input current harmonics and excessive neutral currents. The neutral current mainly composes triplen harmonic currents, and the zero-sequence neutral current flows through the neutral conductor. The zero-sequence harmonic current and the zero-sequence fundamental component of the non-linear load current, the resultant sum of these two currents gives the total neutral current. In order to overcome the above problem it is necessary to employ a zigzag transformer, which mitigates the triplen harmonics and zero-sequence currents in the primary winding itself thereby keeping the secondary free from triplen harmonics and zero-sequence currents. Also the six-leg voltage source converter eliminates harmonics and acts like a load balancer [18]. The implementation of the zigzag transformer reduces the KVA rating of the devices used in voltage source converter [19]. In general the PI controller is not completely adequate to regulate high frequency harmonics; hence the necessity to employ PID plus Vector PI controller to achieve good control of current controller and the Vector PI controller is an alternative version of resonant controller which has superior and robust characteristics to mitigate the high-order harmonic currents [20]. For the controller to effectively regulate the supply current, the controller must have high gain at harmonic frequencies.

II. System Configuration and Operation

The proposed stand-alone system constitutes an asynchronous generator, an excitation capacitor, linear and nonlinear consumer loads, and the proposed IELC is shown in Fig. 1. The modeled integrated electronic load controller incorporates six-leg insulated-gate bipolar- junction-transistor-based voltage source converter along with a dc-bus capacitor, a chopper switch, and an auxiliary load on its dc link. Using interfacing inductors, the IELC is connected at the point of common coupling (PCC). A dc-bus capacitor is employed in order to have a self-supporting dc bus and minimize voltage ripple. The VAR requirement of the isolated asynchronous generator is met by the three-phase star connected capacitor bank. The capacitor bank value is selected in a way to generated rated voltage at no-load. In the event of load perturbation, the active power difference between the constant power generated by isolated asynchronous generator and the load power is consumed by auxiliary of the dc chopper of the integrated electronic load controller. Depending upon the changes in load, the integrated electronic load controller accordingly regulates the terminal voltage, due to which the voltage and frequency of the system remains unaffected and constant [19].

The adaline based control strategy is shown in Fig. 2. Adaline algorithm for the control of integrated electronic load controller is used to carry out the estimation of reference source current, which is easy, simple and fast method to extract the three-phase positive-sequence fundamental-frequency active and reactive load currents. The advantages of the adaline based techniques are:

1. Adaline with online weight calculation responds well for severe load perturbation [12]-[14].
2. The adaline technique doesn't require low-pass filter, therefore reducing complexity in computation [19].

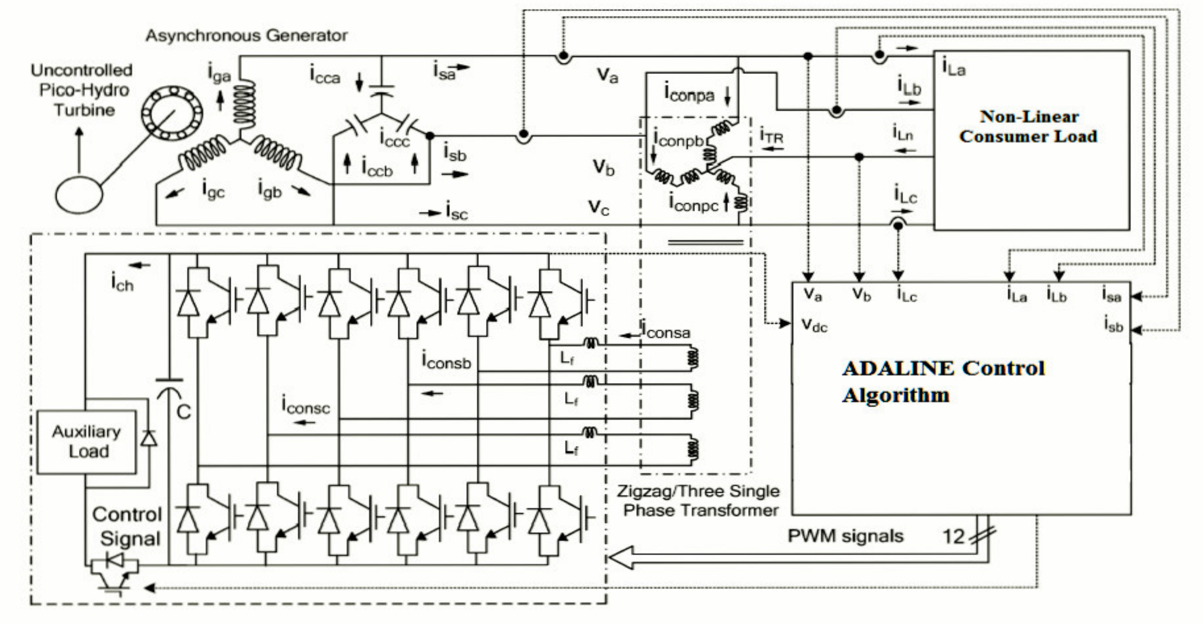


Fig.1. Schematic diagram of IAG with IELC

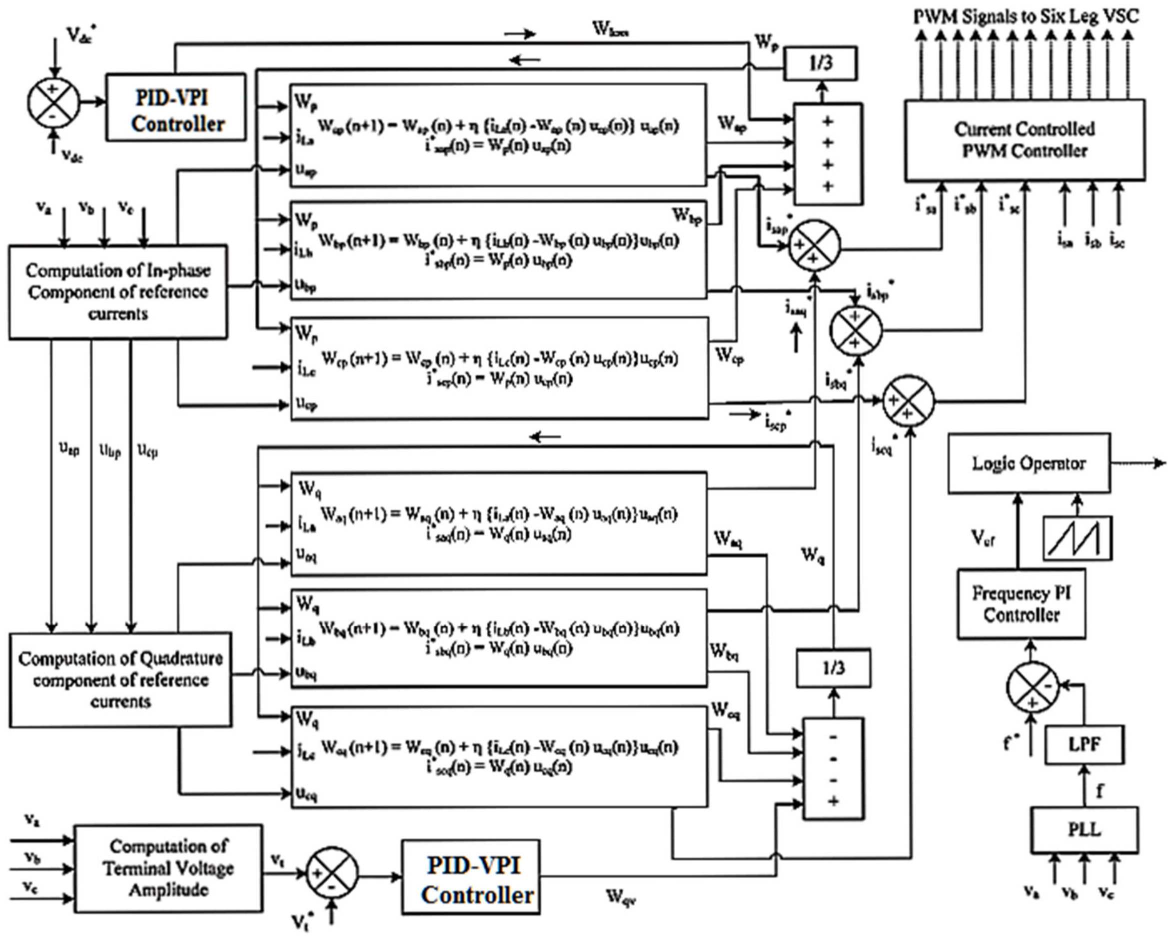


Fig. 2. Adaline control algorithm

III. Control Scheme

The basic equations of this control algorithm are as follows

A. In-phase component of reference source currents

$$V_t = \{(2/3)\,(V_a^2+V_b^2+V_c^2)\}^{1/2} \qquad (1)$$

Where, V_a, V_b, V_c are the three phase voltages at the isolated asynchronous generator.

The unit vector in phase with v_a,v_b,v_c is obtained as

$$u_{ap} = v_a/V_t \qquad u_{bp} = v_b/V_t \qquad u_{cp} = v_c/V_t \qquad (2)$$

Where, u_{ap} , u_{bp} , u_{cp} are unit vector in phase.

The error in the dc bus voltage of the voltage source converter ($V_{dcer(n)}$) of the integrated electronic load controller at nth sampling instant is

$$V_{dcer(n)} = V^*_{dc(n)} - V_{dc(n)} \qquad (3)$$

Where,

$V^*_{dc(n)}$ is the reference dc voltage

$V_{dc(n)}$ is the sensed dc-link voltage

The output of the PID-VPI controller [20] for maintaining the dc bus voltage of the voltage source controller of the integrated electronic load controller

$$W_{loss(n)} = G_{PI-VPI} = K_{P1} + \frac{K_{I1}}{s} + K_{d1}s + \sum_{h=6,12,18...} 2\frac{k_{ph}s^2 + k_{rh}s^2}{s^2+(h\omega_s)^2} \qquad (4)$$

Where $W_{loss(n)}$ is considered as part of the active-power component of the source current, K_{ph} and K_{rh} are proportional and resonant gains of the resonant controller.

Therefore, the average weight of the fundamental reference active-power component of the source current is given as

$$Wp(n) = \{ W_{loss}(n) + W_{ap}(n) + W_{bp}(n) + W_{cp}(n)\}/3 \qquad (5)$$

The fundamental components active-power of the load currents is based on least mean square (LMS) algorithm. The weights of the active-power component of the three-phase load current are estimated as

$W_{ap}(n+1) = W_{ap}(n) + \eta\{i_{La}(n)-W_{ap}(n)u_{ap}(n)\}\ u_{ap}(n)$ (6)

$W_{bp}(n+1) = W_{bp}(n) + \eta\ \{i_{Lb}(n)-W_{bp}(n)u_{bp}(n)\}\ u_{bp}(n)$ (7)

$W_{cp}(n+1) = W_{cp}(n) + \eta\{i_{Lc}(n)u_{cp}(n)\}u_{cp}(n)$ (8)

Where η is the convergence factor, it decides rate of convergence and accuracy of estimation. The practical value of η lies between 0.01 and 1.0.

The three-phase fundamental reference active-power components of the source currents are expressed as

$i^*_{sap} = W_p\ u_{ap}$ $i^*_{sbp} = W_p\ u_{bp}$ $i^*_{scp} = W_p\ u_{cp}$ (9)

B. Quadrature Components of Reference Source Currents

The unit vector in quadrature with v_a, v_b, v_c maybe derived using quadrature transformation of the in-phase unit vectors u_{ap} , u_{bp} , $u_{cp.}$

$u_{aq} = -\ u_{bp}/\sqrt{3} + u_{cp}/\sqrt{3}$ (10)

$u_{bq} = \sqrt{3}\ u_{ap}/2 + (u_{bp} - u_{cp})/2\sqrt{3}$ (11)

$u_{cq} = -\sqrt{3}\ u_{ap}/2 + (u_{bp} - u_{cp})/2\sqrt{3}$ (12)

The amplitude of the IAG terminal voltage and its reference value (Vtref) are fed to a PI voltage controller. The voltage error Ver is the amplitude of the ac voltage at the nth sampling instant

$V_{er}(n) = V_{tref}(n) - V_t(n)$ (13)

The output of the PID-VPI controller for maintaining the of the ac terminal voltage to a constant value at the nth sampling instant is expressed as

$$W_{qv(n)} = G_{PI-VPI} = K_{PI} + \frac{K_{i1}}{s} + K_{d1}.s + \sum_{h=6,12,18...} 2\frac{k_{ph}s^2{}_{+}\,k_{rh}s^2}{s^2+(h\omega_s)^2} \quad (14)$$

Where,

K_{pa} and K_{ia} are the proportional and integral gain constants of the PI controller

$V_{e(n)}$ and $V_{e(n-1)}$ are the error in voltages of nth and (n-1)th instant.

$W_{qv(n-1)}$ is the amplitude of the quadrature component of the reference fundamental current at (n-1)th instant.

The weights of the reactive-power components of the three-phase load currents are estimated as

$W_{aq}(n + 1) = W_{aq}(n)+ \eta\ \{i_{La}(n)-W_{aq}(n)u_{aq}(n)\}\ u_{aq}(n)$ (15)

$W_{bq}(n + 1) = W_{bq}(n)+ \eta\ \{i_{Lb}(n)-W_{bq}(n)u_{bq}(n)\}\ u_{bq}(n)$ (16)

$W_{cq}(n + 1) = W_{cq}(n)+ \eta\ \{i_{Lc}(n)-W_{cq}(n)u_{cq}(n)\}\ u_{cq}(n)$ (17)

The average weight of the fundamental reference reactive component of the generator current is

$W_q(n) = [W_{qv}(n) - \{W_{aq}(n) + W_{bq}(n) + W_{cq}(n)\}]\ 1/3$ (18)

The three phase fundamental reference reactive-power components of the source currents are given as

$i^*_{saq} = W_q u_{aq}$ $i^*_{sbq} = W_q u_{bq}$ $i^*_{scq} = W_q u_{cq}$ (19)

C. Reference source currents

The total reference source currents are the sum of the in-phase and the quadrature components of the reference source currents as

$i^*_{sa} = i^*_{saq} + i^*_{sap}$ (20)

$i^*_{sb} = i^*_{sbq} + i^*_{sbp}$ (21)

$i^*_{sc} = i^*_{scq} + i^*_{scp}$ (22)

These reference source currents (i^*_{sa}, i^*_{sb}, and i^*_{sc}) are compared with the sensed source currents (i_{sa}, i_{sb}, and i_{sc}). The current errors are computed as

$i_{saerr} = i^*_{sa} - i_{sa}$ (23)

$i_{sberr} = i^*_{sb} - i_{sb}$ (24)

$i_{scerr} = i^*_{sc} - i_{sc}$ (25)

These currents errors are amplified using the proportional controller by a gain “K” and which is given as

$V_{cca} = K\ i_{saerr}$ (26)

$V_{ccb} = K\ i_{sberr}$ (27)

$V_{ccc} = K\ i_{scerr}$ (28)

These amplified current-error signals (V_{cca}, V_{ccb}, V_{ccc}) are compared with fixed-frequency (10-kHz) triangular wave to generate unipolar PWM switching signals to generate the gating signals for the six-leg VSC (each phase consists of three H-bridge VSCs) of the IELC. For switching on the H-bridge VSC of phase “a,” the basic logic is

$Vcca > V$tri (upper device of the left leg of phase a on)

$Vcca \le V$tri (lower device of the left leg of phase a on) (29)

$-Vcca > V$tri (upper device of the left leg of phase a on)

$-Vcca \le V$tri (lower device of the left leg of phase a on) (30)

Where, Vtri is taken as the instantaneous value of the fixed- frequency triangular wave and a similar logic is applied to generate the gating signals for the other two phases.

D. Chopper PWM Controller

The frequency error of the isolated asynchronous generator voltage is defined as

$$f_{er}(n) = f^*_{(n)} - f_{(n)} \quad (31)$$

Where, f* is the reference frequency (50 Hz in the present system) and "f" is the frequency of the voltage of the isolated asynchronous generator. The instantaneous value of *f* is estimated using the phase-locked loop over the ac terminal voltages (v_a , v_b , and v_c), as shown in Fig. 2.

At the *n*th sampling instant, the output of the frequency PID controller is

$$V_{cf}(n) = V_{cf(n-1)} + K_{pf}\ \{ f_{re(n)} - f_{re(n-1)} \} + K_{if}\ f_{re(n)} \quad (32)$$

This output of the frequency controller $V_{cf(n)}$ is compared with the fixed-frequency triangular carrier wave (3 kHz in this case) to generate the gating signal of the insulated-gate bipolar transistor (IGBT) of the chopper of integrated electronic load controller.

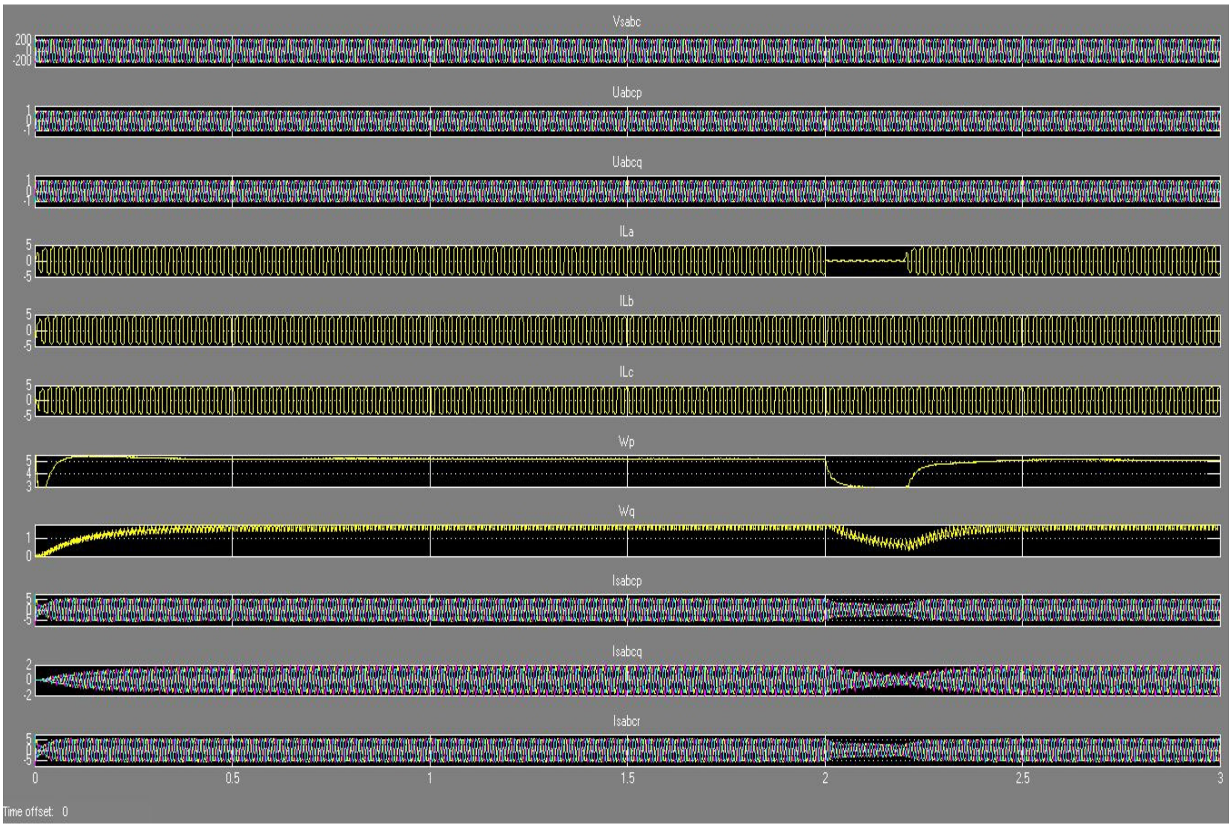


Fig. 3. Signals extracted from adaline control algorithm

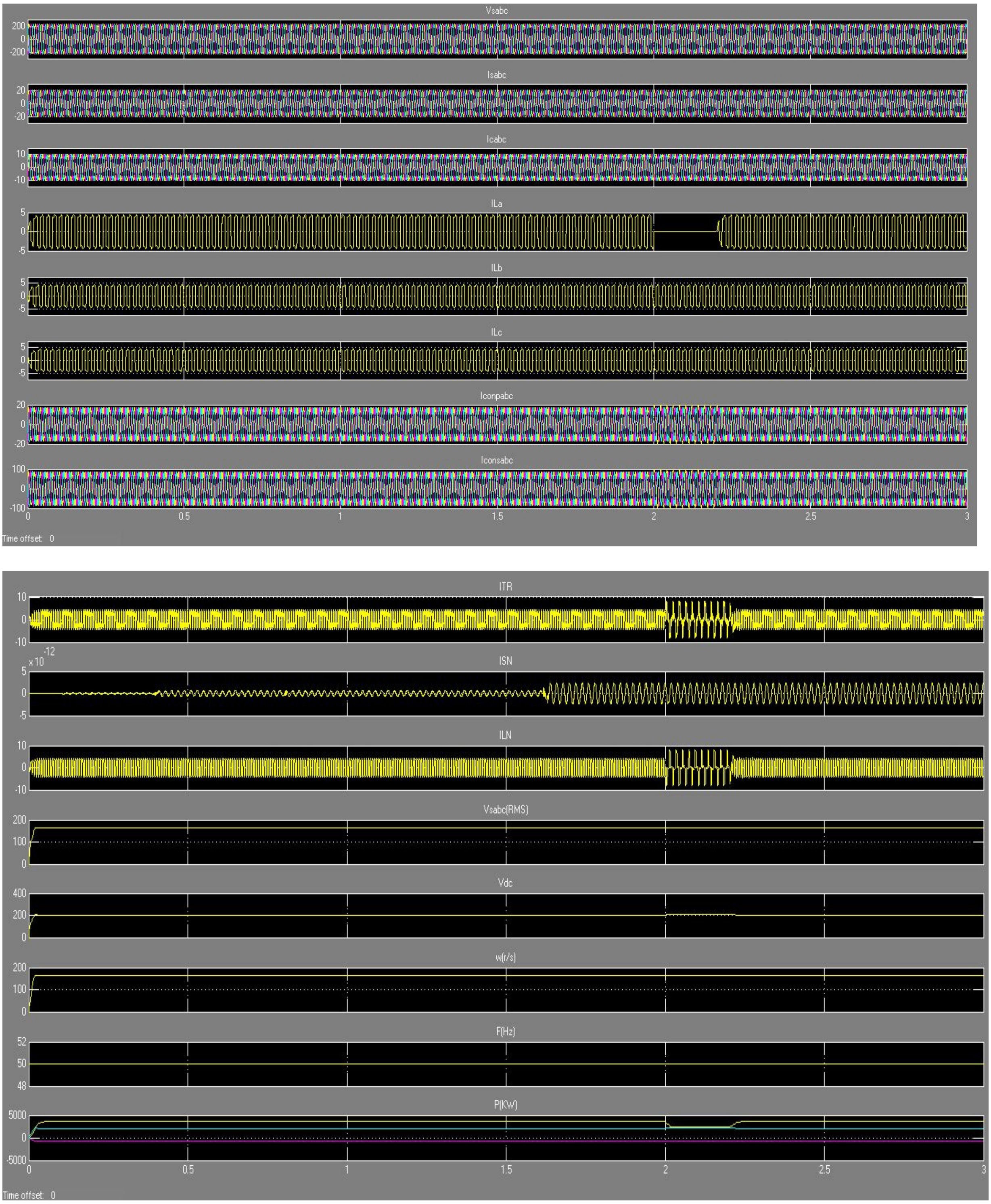
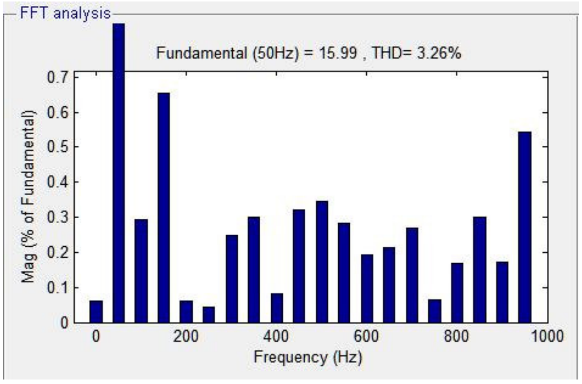
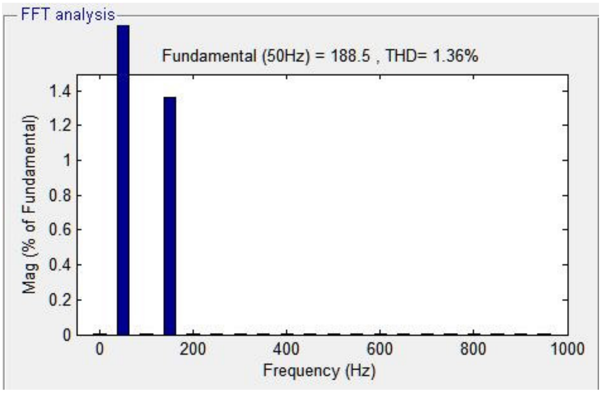


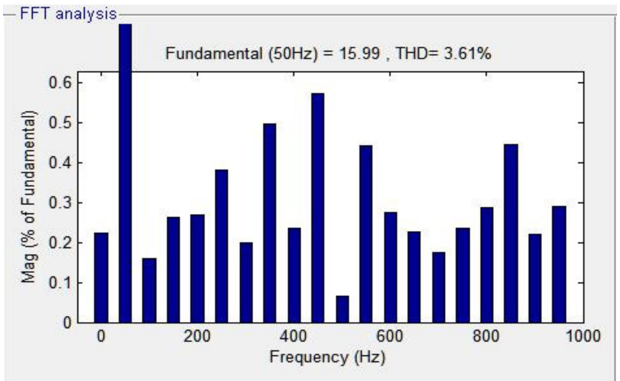
Fig. 4. Performance of the Stand-alone system feeding three-phase four-wire loads.



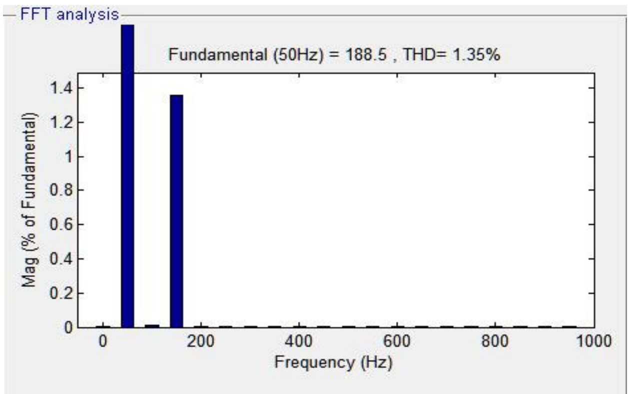
Harmonic spectra of generating current with PID-VPI.



Harmonic spectra of generating voltage with PID-VPI.



Harmonic spectra of generating current with PI controller.



Harmonic spectra of generating voltage with dc bus PI controller.

IV. Matlab Modelling

The simulation model of the proposed system is carried out by employing 3.7-KW 230-V 50Hz Y-connected asynchronous machine and 4-Kvar stay-connected excitation capacitor bank. The zigzag/ three single-phase multi winding transformers of rating 80V/80V/80V are used to compensate the neutral currents and to regulate the dc bus voltage of the integrated electronic load controller to an optimal level. The non-linear load is used in the system to demonstrate the effectiveness of the integrated electronic load controller. The simulations are run in discrete mode at 10 x 10^{-6} step size using the solver configuration ode23tb (stiff/TR-BDF-2).

V. Simulation Results

The simulation result shows the execution of the propound integrated electronic load controller with adaline control algorithm is observed for a constant input power uncontrolled small hydro-turbine-driven isolated synchronous generator feeding non-linear three-phase four-wire loads. All three single-phase loads are fed by isolated asynchronous generator at 1.9s. At 2s, one phase load is detached which results in excessive amount of active power to the auxiliary load of the integrated electronic load controller, diverted by the isolated asynchronous system. The detached phase load is reapplied to the system at 2.2s, due to which an increased power is fed by isolated asynchronous generator to the auxiliary load of the integrated electronic load controller to the non-linear load. There is a reduction in total harmonic distortion (THD) of the generator current and voltage waveform by implementing PID-VPI controller, which is 3.26% and 1.36% respectively. If we implement PI controller, then we get THD of the generator current and voltage waveform are 3.61% and 1.35% respectively. Therefore the implementation of the PID-VPI controller has minimized the THD to a lower value than the PI controller. The THD of the terminal voltage and current is well within 5%, the limitation proposed by the IEEE-519 standards.
Figs. 3 and 4 show the waveforms of the IAG terminal voltages (*vsabc*), source currents (*isabc*), capacitor-bank current (*icabc*), load currents (*iLa* , *iLb* , and *iLc*), compensator primary currents (*i*conp), compensator secondary currents (*i*cons), zigzag transformer neutral currents (i_{TR}), load neutral current (i_{ln}), dcbus voltages (*vdc*), IAG speed (*ωr*), reference and sensed frequencies (*f*), and powers for the source (*PG*), auxiliary load (*PA*), and consumer loads (*PL*) during different load conditions, in-phase unit templates (*uabcp*), quadrature unit templates (*uabcq*), average of in-phase weights (*Wp*), average of quadrature weights (*Wq*), in-phase reference source currents (*isabcp*), quadrature reference source currents (*isabcp*), and reference source currents (*i*sabc*), demonstrating the extraction of the fundamental load currents using the adaline algorithm.

APPENDIX

A. Parameters of 3.7-kW 230-V 50-Hz Y-Connected Four-Pole Asynchronous Machine

Rs = 0.3939 Ω, *Rr* = 0.4791 Ω, *Xlr* = 0.6335 Ω,
Xls =0.7898 Ω, *Xm* = 24.08114 Ω

B. Controller Parameters

Lf = 2.5 mH, *C*dc = 1650 *μ*F, and *Rd* = 10Ω
DC-bus voltage of VSC: 200 V
AC voltage PID controller: *Kpa* = 0.3, *Kia* = 0.3, *Kid* = 0.001
Frequency PID controller *Kpf* = 0.1, *Kif* = 0.1, *Kid* = 0.001
Convergence factor *η* = 0.1, *K* = 1

C. Prime Mover Characteristics for Simulation

*T*shaft = (*K*1 − *K*2 *ωm*); *K*1 = 1470, *K*2 = 8.5.

VI. Conclusion

The stand-alone uncontrolled hydro turbine-driven asynchronous generator has been modeled and simulated, its performance is observed and studied under non-linear load condition using LMS algorithm with PID-VPI controller, for critical evaluation of the system non-linear load is considered, as it has the capability to inject harmonics into the system. It is observed that the proposed system performance has enhanced by the application of PID-VPI controller when compared with PI controller. PI controller is not a suitable solution as it imposes limitation on control bandwidth. The obtained THD of the generator waveform with the application of PID-VPI controller is 3.26%. The performance of the integrated electronic load controller is good under various loading condition, along with load balancing, voltage and frequency control and harmonic mitigation in three-phase four-wire loads. The application of the PID-VPI controller allows governing the system with ease, less complexity and less sensitive to load changes.

References

[1] J. B. Ekanayake, "Induction generators for small hydro schemes," *PowerEng. J.*, vol. 16, no. 2, pp. 61–67, Apr.

2002.
[2] J. M. Elder, J. T. Boys, and J. L. Woodward, "Self-excited induction machine as a low cost generator," *Proc. Inst. Elect. Eng.*, vol. 131, pt. C, no. 2, pp. 33–40, Mar. 1984.
[3] S. Rajakaruna and N. N. Maw, "Unregulated performance of an induction generator in an isolated micro hydro power plant," in *Proc. 7th IPEC*, Nov. 29–Dec. 2, 2005, pp. 1–6.
[4] J. Bjornstedt and O. Samuelsson, "Voltage and frequency control for island operated induction generators," in *Proc. IET CIRED Smart Grids Distrib. Conf.*, 2008, pp. 1–4.
[5] G. Dastagir and L. A. C. Lopes, "Voltage and frequency regulation of astand-alone self-excited induction generator," in *Proc. IEEE Elect. Power Conf.*, Montreal, QC, Canada, Oct. 2007, pp. 502–506.
[6] F. Profumo, B. Colombo, and F. Mocci, "A frequency controller for in- duction generators in stand-by mini hydro power plants," in *Proc. IEEE Elect. Mach. Drives Conf.*, Sep. 1989, pp. 256–260.
[7] Y. Zidani and M. Naciri, "A numerical analytical approach for the optimal capacitor used for the self-excited induction generator," in *Proc. Power Electron. Spec. Conf.*, Jun. 2001, vol. 1, pp. 216–220.
[8] B. Singh, G. K. Kasal, and S. Gairola, "Power quality improvement in conventional electronic load controller for an isolated power gen- eration," *IEEE Trans. Energy Convers.*, vol. 23, no. 3, pp. 764–773, Sep. 2008.
[9] W. Jun and Y. Bo, "A novel electronic load controller: Theory and imple- mentation," in *Proc. ICEMS*, 2001, vol. 2, pp. 1276–1278.
[10] J. M. Ramirez and M. E. Torres, "An electronic load controller for the self-excited induction generator," *IEEE Trans. Energy Convers.*, vol.22, no. 2, pp. 546–548, Jun. 2007.
[11] K. H. Youssef, M. A. Wahba, H. A. Yousef, and O. A. Sebakhy, "A new method for voltage and frequency control of stand-alone self-excited induction generator using PWM converter with variable DC link voltage," in *Proc. IEEE Amer. Control Conf.*, 2008, pp. 2486–2491.
[12] B. Singh and J. Solanki, "An implementation of an adaptive control al- gorithm for a three-phase shunt active filter," *IEEE Trans. Ind. Electron.*, vol. 56, no. 8, pp. 2811–2820, Aug. 2009.
[13] A. Bhattacharya and C. Chakraborty, "Adaline controlled 3-phase 3-wire shunt active power filter with enhanced performance using the capacitor voltage feedback," in *Proc. ICIT* , Feb. 10–13, 2009, pp. 1–6.
[14] B. Singh and J. Solanki, "Load compensation for diesel generator based isolated generation system employing DSTATCOM," *IEEE Trans. Ind. Appl.*, vol. 47, no. 1, pp. 238–244, Jan.–Feb. 2011.
[15] G. K. Kasal and B. Singh, "Decoupled voltage and frequency con- troller for isolated asynchronous generators feeding three-phase four- wire loads," *IEEE Trans. Power Del.*, vol. 23, no. 2, pp. 966–973, Apr. 2008.
[16] I. Serban, C. P. Ion, C. Marinescu, and M. N. Cirstea, "Elec- tronic load controller for stand-alone generating units with renewable energy sources," in *Proc. IEEE IECON*, Paris, France, Nov. 2006, pp. 4309–4312.
[17] B. Singh, S. S. Murthy, and S. Gupta, "A stand-alone generating sys- tem using self-excited induction generators in the extraction of petro- leum products," *IEEE Trans. Ind. Appl.*, vol. 46, no. 1, pp. 94–101, Jan./Feb. 2010.
[18] B. Singh, P. Jayaprakash, T. R. Somayajulu, and D. P. Kothari, "Reduced rating VSC with a zig-zag transformer for current compensation in a three- phase four-wire distribution system," *IEEE Trans. Power Del.*, vol. 24, no. 1, pp. 249–259, Jan. 2009.
[19] B. Singh and V. Rajagopal "Neural-network based integrated electronic load controller for isolated asynchronous generators in small hydro generation", *IEEE Trans. Ind. Electron.*, vol. 58, no. 9, pp.4264 - 4274 2011.
[20] Q.-N. Trinh and H.-H. Lee, "An advanced current control strategy for three-phase shunt active power filters", *IEEE Trans. Ind. Electron.*, vol. 60, no. 12, pp. 5400-5410, 2013.

Dipesh Kumar Karmakar born in 1991, India. He received B-Tech degree in Electrical& Electronics Engineering from ANITS, ANDHRA UNIVERSITY, Andhra Pradesh, India in 2013. Currently he is a 2nd year M.Tech student at GITAM University in Power Systems & Automation (2014-2016). His research interest includes Applications of Power Electronics to Power Systems, Power Quality, Power System Operation & Control, Power System Stability & Analysis.

N.G.S RAJU born in 1980, in India. He received B.E degree in Electrical & Electronics Engineering from College of Engineering, GITAM, ANDHRA UNIVERSITY, Andhra Pradesh, India in 2001 and M-Tech degree from College of Engineering, JNTU,Kakinada in High Voltage Engineering in 2008. Currently he is working as an Assistant Professor in GITAM University