Comparison Of UPS Inverter Using PI Controller And NN Controller

[1] S. N. Ambekar, [2] Dr. V. A. Deodhar-Kulkarni
[1, 2] *Govt. College of Engineering, Aurangabad*

***Abstract*:**

Uninterruptible power supplies (UPSes) are used to provide backup power to critical loads, where even a temporary power failure causes large economic losses. The UPSes are used in applications like computer installations, process control in chemical plants, and general communication systems. The function of UPS is to provide a high quality sinusoidal voltage and for this it needs to be controlled. Conventional controllers cannot provide the exact sinusoidal output with the nonlinear loads. The artificial neural network controller having an advantage of adaptability to all loads. The neural network controller is built and trained by using patterns obtained from a simulated controller with multiple feedback loops having an idealized load-current reference. The weights and biases are downloaded to neural network controller and then it is used for online control of inverter. This is to achieve low total harmonic distortion and pure sinusoidal output.

This project proposes the Matlab / Simulink implementation of artificial neural network control of UPS inverter. The type of neural network controller used for UPS inverter is of feed forward type and training algorithm used is back propagation. The training of neural network is made with the help of Matlab NN toolbox. The closed loop simulation results obtained from the neural network controller is compared with PI controller.

***Index Terms*—** Neural network control, UPS inverter.

I. INTRODUCTION:

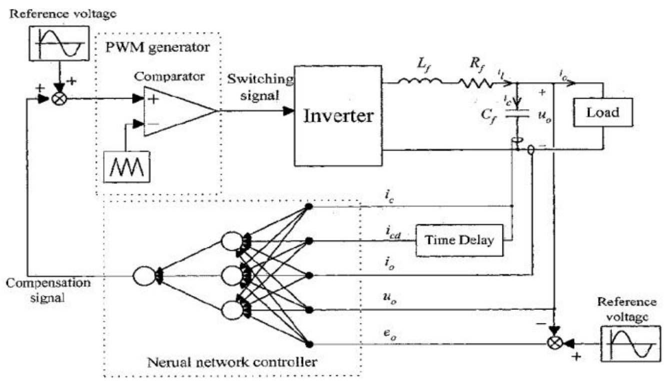
Uninterruptible power supplies are emergency power sources, which have wide spread applications in critical equipments, such as computers, automated process controllers, and in hospital instruments. With the rapid growth in high-efficiency power converters, more and more electrical loads are non-linear and generate harmonics. It is big challenge for a UPS to maintain a high quality sinusoidal output voltage under non-linear loading condition. The high quality sinusoidal output voltage is usually achieved by employing a combination of pulse width modulation (PWM) scheme and a second order filter at the output of the inverter.

A multiple feedback-loop control scheme can be utilized to achieve good dynamic response and low total harmonic distortion. The control scheme is based on sensing the current in the capacitor of the output filter, using it in an inner feedback loop. When the loads are nonlinear, the performance degrades, since such a scheme is developed from a linear system theory.

Neural networks (NNs), it is an interconnection of a number of artificial neurons that simulates a biological brain system. It has the ability to approximate an arbitrary function mapping and can achieve a higher degree of fault tolerance, and successfully introduced in to power electronics. When an NN is used in system control, the NN can be trained either on-line or off-line. In on-line training, since the weights and biases of the NN are adaptively modified during control process, it has better adaptability to non-linear operating condition. The most popular training algorithm for a neural network is back-propagation. It is attractive because it is stable, robust, and efficient. However the back propagation involves a great deal of multiplication and derivation.

Fig. 1 Proposed NN control scheme for a UPS inverter

Parameter	Value	Unit
Switching frequency, f_s	20	kHz
DC source voltage, V_{dc}	48	V
Rated Output Voltage	25	V_{rms}
Rated Output Frequency	50	Hz
Rated Output Current	5	A_{rms}
Rated output impedance	5	Ω
Filter Inductor, L_f	250	μH
Inductor Resistance, R_f	0.2	Ω
Filter Capacitor, C_f	30	μF



The training of a neural network requires a large number of example patterns. These patterns may be obtained from a simulated controller. Although the weights and biases are fixed during the control process, the neural network is a nonlinear system that has much robustness than a linear system. Moreover the forward calculation of neural network involves only addition, multiplication and sigmoid-function of wave shaping. Example patterns are obtained from a simulated controller, which has an idealized load-current reference. After training, the neural network architecture is used to control the UPS inverter in on-line.

The objective of this project is to control inverter output voltage by maintaining it as a high quality sinusoidal shaping in nature with low total harmonic distortion (THD) for UPS applications. This is to be accomplished by an artificial neural network Controller in closed loop further the performance of the UPS inverter with neural network controller is to be compared with PI controller.

II. CLOSED LOOP CONTROL OF UPS INVERTER WITH CONVENTIONAL CONTROLLER

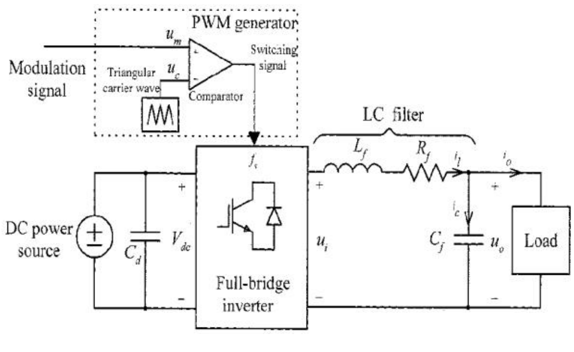


Fig.2

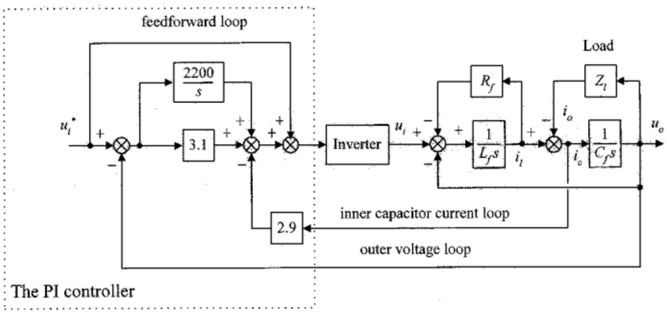


Fig3 Analog PI controller for comparison purpose

The core circuit of the UPS system is the inverter circuit, which is required for power conversion from dc (battery) to ac power. Inverter circuits can be broadly classified into two types,

- ✓ Voltage source inverters(VSI) and
- ✓ Current source inverters (CSI).

A voltage source inverter is one in which the dc source has small or negligible impedance, in other words a voltage source inverter has stiff dc voltage source at its input terminals and constant output voltage at its output. Current source inverter is fed with adjustable current from a dc source of high impedance, i.e. from a stiff dc current source. In a CSI fed with stiff current source, output current wave forms are not affected by load. In voltage source inverters, the input voltage is maintained constant and the output voltage does not depend on the load. However, the waveform of load current as well as magnitude depends upon the nature of the load impedance. In CSI the magnitude of output voltage and its waveform is dependent upon the nature of load impedance. As the UPS systems are mainly known as emergency power sources, they have to produce a constant voltage for that application, which is not furnished by current source inverters. In general all the UPS systems are implemented with voltage source inverters as they can produce the constant output voltage, independent of load.

A multiple feedback loop control scheme is employed in order to have better steady state stability and to achieve good dynamic response. The two loops are outer voltage loop and inner current loop.

The inner current loop provides an inherent peak current limit in the power circuit; in addition, since the capacitor current represents the change of load voltage, the control scheme is capable of predicting near future variations in the load voltage and thus providing a good dynamic response. Further more the outer voltage loop regulates the load voltage and produces a stiff ac voltage supply and ensures a sinusoidal load voltage within the acceptable total harmonic distortion (THD).

In order to reduce the steady state error between the capacitor voltage and its reference waveform a proportional plus integral

(PI) controller is used in fed forward path of outer voltage loop and is designed for resistive load.

III. NEURAL NETWORK CONTROL OF UPS INVERTER

The neural network is an interconnection of artificial neurons. Artificial neural network is a nonlinear network, and has better robustness than linear system, improves the system performance for both the linear and nonlinear type of loads. The many capabilities of neural networks, such as nonlinear functional approximation, learning, generalization, etc are in fact performed due to the nonlinear activation functions of each neuron. The type of activation functions used in neural network control of UPS inverter and back propagation algorithm for training, closed loop control of neural network based UPS inverter is described here

Artificial Neuron

Neural networks are simplified models of the biological nervous systems and therefore have drawn motivation from the kind of computing performed by a brain. An artificial neural network is highly interconnected network of larger number of processing elements called neurons. The basic neuron structure is as shown in figure 3

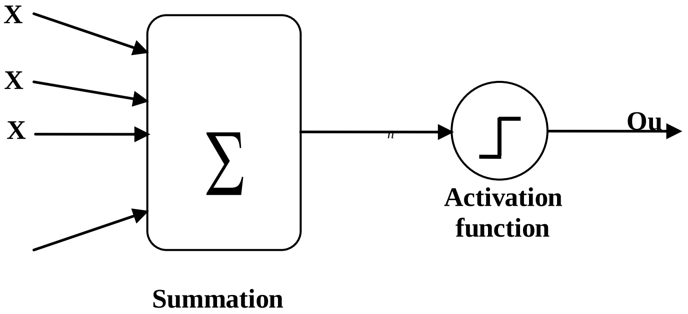


Fig.4 Simple model of artificial neuron

Three basic elements of the neuron model are:

1) A set of connecting links which fetch the input signals to the summation unit. Each of this connecting links is characterized by a weight or strength of its own. The weight of neuron may lie in the range that includes negative as well as positive values.
2) A summation unit or adder, for summing the input signals, weighted by the respective strength of neuron.
3) The last is an activation function for limiting the amplitude of the output of a neuron. The activation function is also referred as squashing function.

As shown in the figure 3, it consists of an input vector, is given by $[X_i]$,

$$[X_i]=[x_1,x_2,x_3,\ldots\ldots\ldots..x_n],$$

the number inputs applied to a neuron, the Weights associated with these inputs are represented by a weight vector $[W_i]$.

$$[W_i]= [w_1,w_2,w_3,\ldots\ldots\ldots w_n].$$

The summation block, correspondingly the biological cell body, adds all the weighted inputs algebraically producing an output called as NET. This may be compactly stated in vector notation as follows

$$\mathbf{NET}=\sum_{i=1}^{n} \mathbf{XiW_i}$$

Feed Forward Back Propagation

These are the networks wherein for every input vector laid on the network, an output vector is calculated and this can be read from the output neurons. There is no feed back. Hence only a forward flow of information is present. Networks having this structure are called as **feed forward networks**.

Back propagation is a systematic method for training multilayer artificial neural networks. It's a multi layer forward network using extend gradient descent based delta –learning rule, commonly known as back propagation, it is trained by supervised learning method.

Training of a network by back propagation involves three stages.

The feed forward of the input training pattern, the back propagation of the associated error, and the adjustment of weights. For training, the hidden layers uses *sigmoid* activation and output layer uses *Purelin* activation functions.

Structure of the Neural Network controller

The distortions in the output voltage of UPS inverters are eliminated by using a neural network in closed loop control. The training of neural network is adopted to ensure that the inverter will have a fast transient response. The structure is shown in figure 6

A neural network controller is realized with a large number of samples of various loading conditions, and training of neural network controller is done properly to learn the control law from the patterns, each time a new set of samples is taken for a change in load.

The neural network shown in figure is a multilayer artificial neural network, comprises of an input layer, output layer and hidden (intermediate) layer of neurons. The multilayered neural Networks provide an increase in computational power over a single layer neural network as there is a nonlinear activation function between the layers.

<u>Obtaining example patterns under linear loading conditions</u>

Under the linear load conditions multiple- feedback-loop control scheme gives better results and is shown in figure. The neural network samples are obtained from a simulated controller shown in figure 6, and these samples are used for the training of a neural network controller. The inner current loop in multiple feedback loop control scheme is changed to a load current loop. A sinusoidal voltage reference is fed to the load model to generate an idealized load –current-reference, Io^*.The error between this current reference and actual load current, Io, is used as the input of the controller.

From the figure 6 a fixed set of controller parameters will not work for all types of loads. Each load is associated with a set of optimal parameters which can be determined from simulations that produce an output voltage with low total harmonic distortion (THD) and a small steady state error. A new example pattern is obtained each time the load model is changed.

The modulation signal to the PWM generator consists of two components, one is sinusoidal feed forward signal, and the other is a compensation signal. So, here the neural network is trained to generate only the compensation signal as its desired output. The inputs to the Neural network controller are filter capacitor current, delayed capacitor current, output current, output voltage and the error between actual and reference voltages. The delay of capacitor current is one switching period.

The selection of an NN should be as simple as possible so as to speed up the control processes. The training of the neural network uses the back propagation algorithm and each time the weights and biases are updated to make the mean square error between the desired output and the actual NN output to an acceptable value. The neural network for this is 5-3-1 structure (one hidden layer and one output layer). All the neurons in hidden layer are having same transfer function of sigmoid type and output neuron is having linear type of transfer function. For the training of a neural network the initial weights and biases are randomly chosen between the ranges of -0.5 to 0.5.The neural network is trained with samples for a certain number of iterations so that the mean square error between desired output and actual neural network output is with in an acceptable value.

.

IV. SIMULATION RESULTS

We simulate the proposed NN controller and PI controller UPS using Matlab toolbox. The steady-state and transient responses of the proposed NN controlled inverter and PI controlled inverter are investigated. **PI controller based UPS inverter**

The Matlab/Simulink implementation of UPS inverter system is shown in figure 5.1 and the UPS inverter specifications are given in table 5.1. The open loop UPS inverter simulation results are obtained and the output voltage and output current wave forms are shown in figure5.2.From the open loop results it is observed that the total harmonic distortion of the output voltage is 2.68%.The figure 5.3 shows the UPS inverter output voltage and current with load changes from no-load to full load.

The Matlab/Simulink implementation of closed loop control of UPS inverter with PI controller is shown in figure 5.4 with k_p=3.1 and K_i=2200.The output voltage and output current waveforms with PI controller is shown in figure 5.5.From the simulation results it is observed that total harmonic distortion of the output voltage is 1.98%.The figure 5.6 shows the PI controller based UPS inverter output voltage and current with load changes from no-load to full-load.

The Matlab/Simulink implementation of closed loop control of UPS inverter with artificial neural network controller is shown in figure 5.7.The neural network specifications are given in the table 5.2.The output voltage and output current waveforms with neural network controller is shown in figure 5.8.From the simulation results it is observed that total harmonic distortion of the output voltage is 1.76%.

The figure 5.9 shows the neural network controller based UPS inverter output voltage and current with load changes from no-load to full-load. It is observed that the dynamic response of the system is improved compared to the conventional PI controller.

The output voltage and load current waveforms of the inverter system for a full resistive load (5ohm) are depicted as below. The figure shows that the proposed NN controlled UPS inverter is capable of producing a good sinusoidal output voltage.

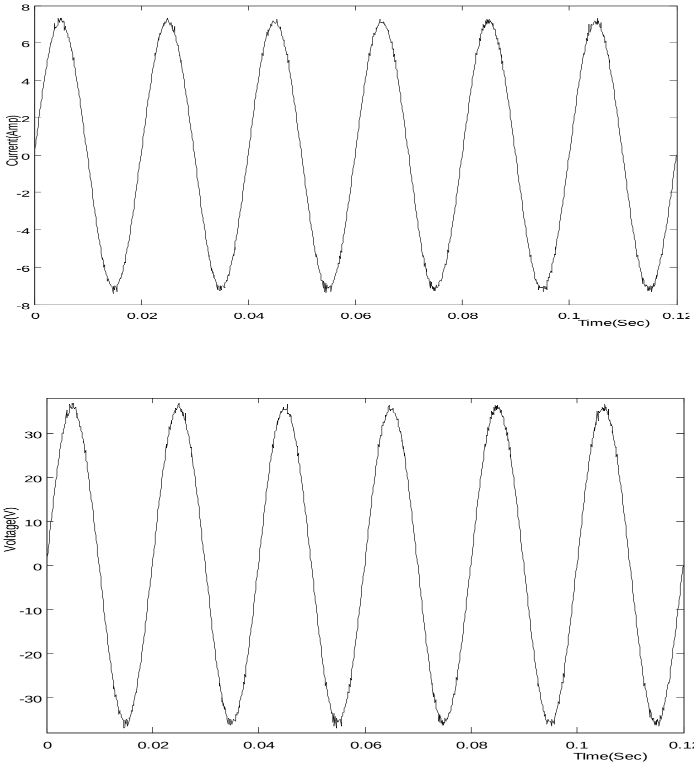


Fig.5 Inverter output current and voltage with PI controller

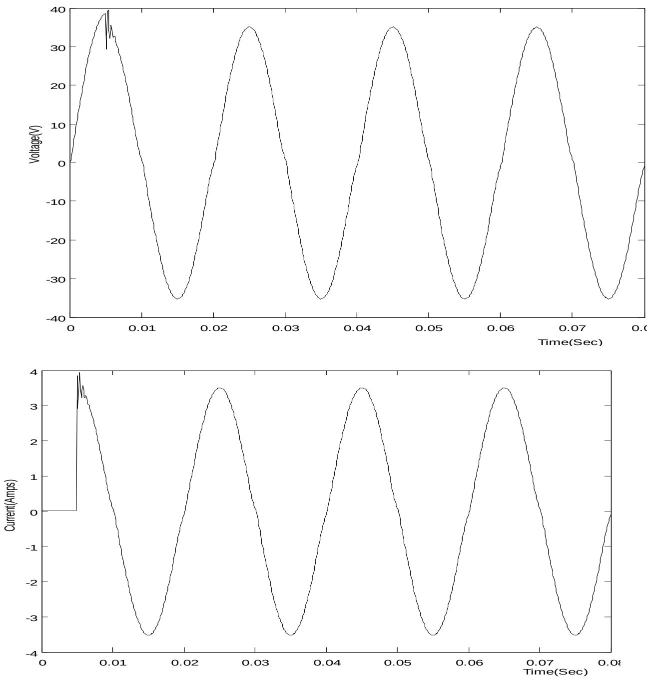
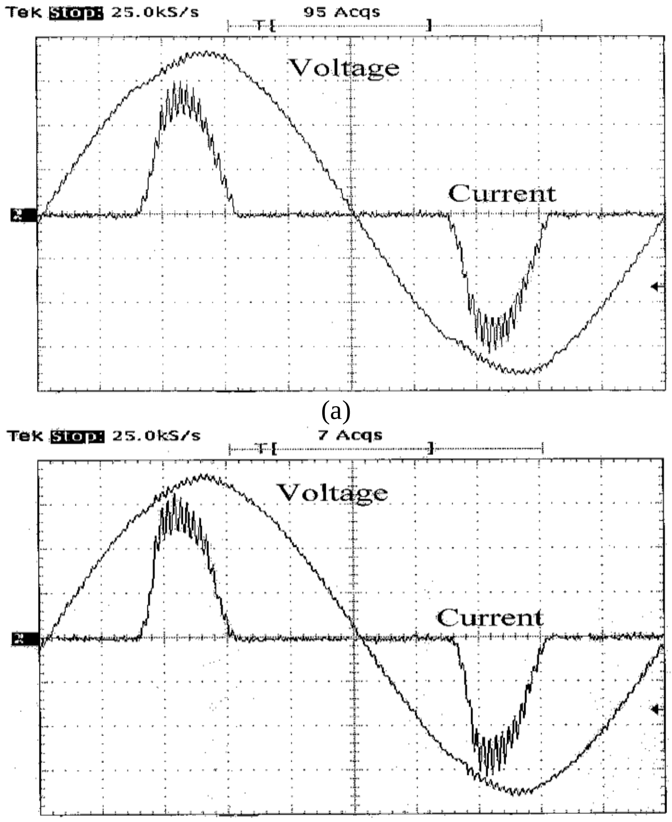


Fig 6 Inverter output voltage and current with change in load from no-load to full load with neural network controller



(a)

(b)

Fig:7 Experimental results forfullwave diode bridge rectifier (3200 _F 10)(a) PI controlled UPS Inverter (b) NN Controlled UPS inverter

Fig. 7 compares the output voltage and load current waveforms of the NN controlled inverter with those of the PI controlled inverter for a full-wave bridge-rectifier load, whose output is connected directly to a 3200 F capacitor in parallel with a 10 resistor.

Fig. 8 compares the THD of the output voltage of the NN controlled inverter with that of the PI controlled inverter under different rectifier-type loads. It is found that the NN controller significantly outperforms the PI controller.

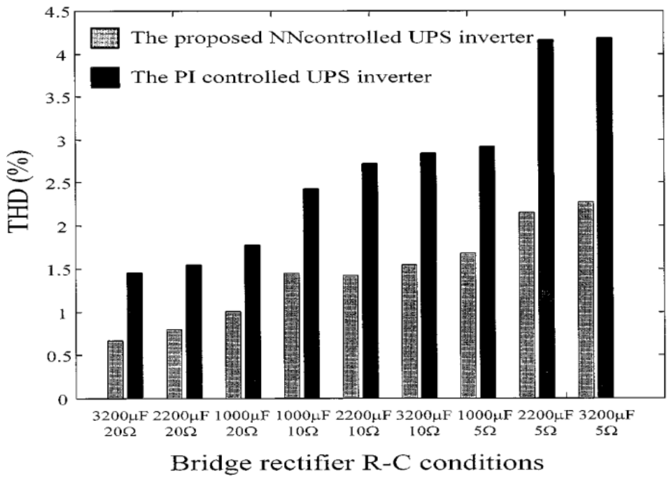


Fig. 8. Comparison of the THD of the output voltage under different rectifier-type loads

CONCLUSIONS

The design and implementation of UPS inverter system with conventional PI controller and artificial neural network controller are developed using Matlab/Simulink toolbox. The open loop and closed loop simulation results of the UPS inverter system with conventional PI controller and artificial neural network controller are obtained, analyzed and compared. From the simulation results it is observed that the artificial neural network controller based UPS inverter system gives less THD in the output voltage and better performance compared to the PI controller.

REFERENCES

[1]. P.D.Ziogas, "Optimum voltage and harmonic control PWM techniques for three-phase static UPS inverters," IEEETrans.Ind,Applicat.vol.IA-16,no.14,pp.542-546,July/Aug 1980.

[2]. N.M.Abdel-Rahim and J.E.Quaicoe, "Analysis and design of a multiple feedback loop control strategy for single phase voltage source UPS inverters," *IEEE Trans.Power Electron*. vol.11, pp, 532-541, July1996.

[3]. M.J.Ryan, W.E.Brumsickle, and R.D.Lorenz, "Control topology options for single phase UPS inverter,"*IEEE Trans.Ind.Applicat*.vol.33,pp,493-501,Mar/Apr.1997.

[4]. B.K.Bose, "Expert systems, fuzzy logic, and neural network applications in power electronics and motion control,"*Proc.IEEE*, vol.82.pp.1083-1112, 1992.

[5]. D.Daniolos,M.K.Darwish,and P.Mehta, "Optimized PWM inverter control using artificial neural networks," Electron Lett.,vol.31,no.20,pp,1739-1740,1995.

[6]. B.R.Lin and R.G.Hoft, "Power electronics inverter control with neural netwoks,"in Proc.IEEE-APEC, 1993, pp.128-134.

[7]. "Introduction to neural networks using matlab 6.0"- S.N Sivanandam,S Sumathi,S.N Deepa,Tata mcgrahill publishers.

[8]. Xiao Sun, Martin H. L. Chow, Member, IEEE, Frank H. F. Leung, Member, IEEE, Dehong Xu, Yousheng Wang, and Yim-Shu Lee, " Analogue Implementation of a Neural Network controller for UPS Inverter Applications."

[9]. Mohammad H.Rashid, "Power Electronics Circuits Devices and Applications," 2nd Edn. Prentice Hall

[10]. "Using MATLAB," The mathworks,Inc.