POWER CONDITIONING IN BATTERY CHARGERS USING SHUNT ACTIVE POWER FILTER THROUGH NEURAL NETWORK

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ABSTRACT

In this paper, single layer perceptron control algorithm is presented for a single phase shunt active power filter to improve the power factor and to reduce the source harmonics. This control scheme is based on a neural harmonic estimator. The reference current signal generated by this neural harmonic estimator is used to generate gating control pulses for active power filter switches. The control scheme have two control loops namely dc voltage regulation loop and current control loop. The performance of the proposed neural harmonic estimator is evaluated and compared with a linear reference generator based control scheme, incorporating the same voltage and current control loops as in the proposed controller. The proposed APF controller forces the supply current to be sinusoidal, with low current harmonics, and to be in phase with the voltage. Simulations are carried out using Matlab Simulink and the results show that the proposed system is capable of compensating the harmonic current to acceptable level.

KEYWORDS: *Active power filter, Harmonics, single layer Perceptron, feedfoward Neural network, Selective compensation.*

I. INTRODUCTION

Harmonic compensation have become increasingly important due to the intensive use of power converters and other nonlinear loads which results in the deterioration of power system voltages and current waveforms. Thus the current wave form can become quite complex depending up on the type of load and its interaction with other components in the system. One of the major effects of power system harmonics is to increase the current in the system. It also causes other problems like greater power losses in distribution and operation failure of protection devices. Due to these problems the quality of electrical power is an object of great concern. Power line conditioner like Active Power filter (APF) can be used to minimize the harmonic distortion current [1]-[3]. The main purpose of shunt active power filter is to supply the harmonic current absorbed by the system. To this end the control of APF systems has great importance.

For the reference-signal generation, by means of direct method consists of sensing the load current and extracting the harmonic content [4]- [5]. As an alternative, the indirect method generates a sinusoidal reference signal by means of grid-voltage sensing. In that case, the grid current is forced to follow this sinusoidal signal, and thus, the load harmonics are indirectly given by the APF inductor current [6]–[8].

The linear reference generator based control strategy consists of two control loops and a resonant selective harmonic compensator. Reference signal is generated by indirect method [6]. That is by means of sensing the grid voltage. Resonant selective harmonic compensator is used for generating reference signal. It consists of several generalized integrators like second order band pass filter with high gain and low band width. Thus it will not affect the dynamics of control loop. The reference signal tracking is performed by the inner current loop. Outer voltage loop is accountable to regulate the capacitor voltage. The main advantages of this method are that good dynamic and transient performance obtained. By this approach most harmful harmonics from load current can be eliminated. In this method harmonics are processed individually.

In order to improve the performance of the inner current loop, optimal, neural, and model reference adaptive controls have been used recently [13]–[15]. Other approaches utilize nonlinear regulators, such as sliding-mode control and hysteretic control [16], [17]. All the previously mentioned controls attenuate the current harmonics only to a certain level.

In this paper, the design of shunt active power filter based on single layer feedforward neural network is presented. The proposed ANN control scheme consists of three control blocks namely voltage control, current control and a neural reference generator. The reference current signal generated by this neural reference generator contains the harmonic components that will be eliminated. This reference signal is controlled by means of a PI controller, which in turn, controls the pulse width modulation (PWM) switching pattern generator [5]-[8]. The output of the PWM generator controls the power switches. The neural reference generator and the other two control block play an important role in the dynamic response of the system. These blocks determine the accuracy and order of the harmonics to be injected. Neural reference generator has inherent learning capability that can give improved precision by interpolation unlike the standard look up table method and space vector modulation. The reference current can be determined using the distorted source current of the system [16]. This paper is organized as follows. Section II describes the active power filter topology. Section III presents the estimation of compensating current. Section IV explains the control of active filter. Section V verifies the expected features of both controllers by means of matlab simulation results. Section VI is conclusion.

II. ACTIVE POWER FILTER FOR BATTERY CHARGER

Battery charger is used as the nonlinear load in the system shown in fig. 1. It draws a non sinusoidal current from supply. In this work, the load consists of a four diodes full bridge rectifier with a capacitor in parallel with a resistor in the dc side.

Active power filters are the best known tool for the current harmonic compensation. Fig.1 shows the schematic diagram of a single phase active power filter in a closed loop manner. Diode bridge rectifier with resistor and capacitor connected in parallel act as a nonlinear load The APF can be controlled in a proper way to attain high resistance against higher order harmonics produced by the load. The active power filter through its control mechanism shapes the grid current to sinusoidal. The compensation principle of shunt active power can be explained as follows. Under normal condition the supply voltage can be represented as

$$v_s(t) = v_m \sin wt \qquad (1)$$

But when the non linear load is connected to the supply, it will draw non sinusoidal current. Thus the load current will contain fundamental component and all other higher order harmonics. It can be represented as

$$i_L(t) = \sum_{n=1}^{\infty} I_n \sin(nwt + \theta_n) \qquad (2)$$

The shunt connected active power filter will generate a harmonic current $i_F(t)$ which compensate the harmonics present in the source current and make source current purely sinusoidal in nature.

$$i_s(t) = i_F(t) + i_L(t) \qquad (3)$$

The compensation current i_F is exactly equals to the harmonic content of the load current i_L. Hence APF needs to calculate i_F accurately and instantaneously.

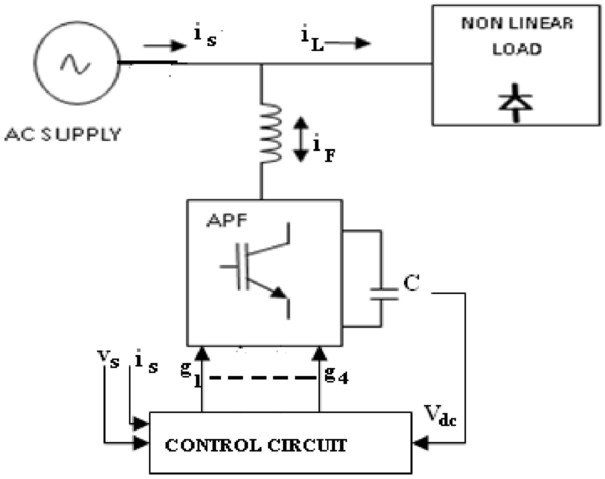

Fig. 1. Active power filter circuit

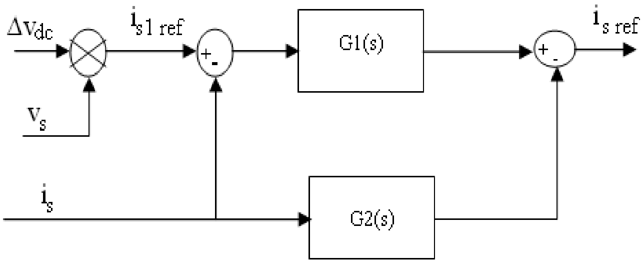

Fig. 2. Linear Reference generator

III. Estimation of Compensating Current

This section deals with the reference current generating schemes, including the linear resonant selective harmonic compensator and proposed neural harmonic estimator.

3.1 Linear Reference Generator

In the basic approach of reference generation grid voltage v_s is multiplied with *k(t)* [6]-[8]

$$I_{sref} = v_s . k(t). \quad (4)$$

In this method reference signal will follow the sensed grid voltage. It will result in the reflection of distortions in the grid voltage. In order to overcome this drawback, a controller with linear harmonic compensator can be used which is as shown in Fig 2. This generator uses a band pass filter $G_1(s)$ and a harmonic compensator $G_2(s)$. Grid voltage v_s and supply current i_s is processed through these filters and produces the reference signal. Band pass filters of $G_2(s)$ have closed loop operation

$$G_1(s) = \frac{2\delta\omega ks}{2+2\delta\omega s+(\omega)2} \quad (5)$$

$$G_2(s) = \sum_{n=3}^{h} 2\frac{\delta n\omega kns}{s2+2\delta n\omega s+(n\omega)2} \quad (6)$$

Where δ is the damping factor, $\omega = 2\pi f$, and k is the gain at the fundamental frequency f. n can take the values of 3, 5, . . . N, where N is the highest current-harmonic component to be attenuated, and kn is the band pass gain of each filter.

3.2 Neural Harmonic Estimator

In this method, the linear reference generator scheme is replaced by artificial neural network (ANN) made up of single layer perceptron. The ANN is trained offline, using a set of training data generated by Fourier analysis of the source current. In neural networks, there are two main processes involved-training and testing. In the training process, the network is trained with suitable input and output patterns which is called data set, so that the outputs of the neural network approximate the target values for various input training patterns in the training set. In the testing process, the performance of the network is verified by using the data outside the training data set.

Neural network for a harmonic component detection is consisted of 2-layers network which input layer =49 units, and a single output layer. Before feeding data to ANN, the source current signals are sampled at a uniform rate Δt in a half cycle of voltage source as shown in Fig 3. So time values are discrete, kΔt with $k=0$, 1, 2….. and then given to the ANN for its training, together with the expected output.

The input is given as a continuous variable. The input signal flows through a gain or weight. The weights can be positive or negative corresponding to acceleration or inhibition of the flow of signals. The summing node produces a weighted sum of signals with a bias value which is initially taken as zero. It then passes to the output through the transfer function which is usually nonlinear, such as sigmoid, inverse-tan, hyperbolic or Gaussian type. When a set of input values are presented to the ANN, step by step calculations are made in the forward direction to drive the output pattern. A cost functional given by the squared difference between the net output and the desired net output for the set of input patterns is generated and this is minimized by gradient descent method altering the weights one at a time starting from the output layer

After training next is the testing phase. In this period we have value of weighing vectors and best output. Using these data we can find out the best value of reference current generated. Current regulation is performed using a PI controller Fig.3 shows the block diagram of APF control scheme based on neural reference generator. The neural reference generator will perform the task of current harmonic computation and generate reference current signal. This current will send to current control block which can be realized using a PI controller. The output of PI controller is a control voltage signal which produces gating pulses for inverter control through PWM generator.

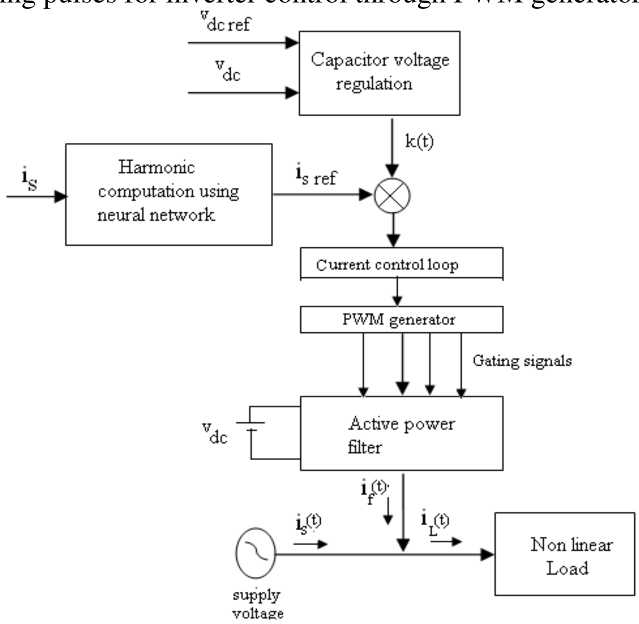

Fig.3. APF control scheme based on neural harmonic estimator

IV. CONTROL OF ACTIVE FILTER

Indirect control method includes an outer voltage control loop and inner current control loop. In the indirect control the reference signal is generated by sensing the grid voltage and grid current is forced to follow this sinusoidal signal. This will reduce the harmonics present in the grid current.[7]-[8].. Indirect current control scheme attenuate the current harmonics to a high level, while maintaining the stability. By this method more harmful harmonics can be easily attenuated. The reference current generated by this method contain information regarding dominating harmonic content that need to be eliminated.

4.1 DC Voltage Regulation Loop

Outer voltage loop is responsible for the capacitor voltage regulation. Fig 4 shows the block diagram of outer voltage loop. In the outer voltage loop, square of the capacitor voltage is compared with squared reference voltage. The output is regulated with the help of PI compensator [13]-[14]. Squared values are used in order to make the design of loop simpler. In order to reduce the ripple at the output of PI compensator, a LPF can be added. The cutoff frequency of LPF can be made less than twice the grid frequency

4.2 Current Control Loop

Inner current control loop will track the reference signal generated by the reference generator. Fig.5 shows the block diagram of current control loop. Through this current control, grid current is forced to follow the reference current created. The error signal is regulated using a PI compensator and control signal is generated. This control signal is used to generate gating pulses to shunt active power filter through PWM technique

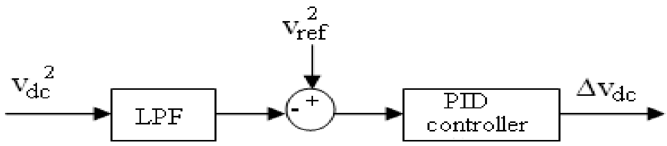

Fig.4. Outer voltage loop

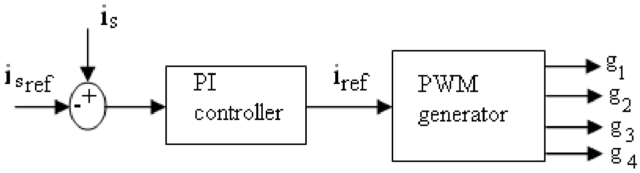

Fig.5 Current control loop.

System Parameters are specified in Table I.

Table I

Symbol	System Parameter	Value
V_s	Grid Voltage	230V
f	Grid frequency	50Hz
R_s	Nonlinear load series resistance	4 ohm
R	Nonlinear load resistance	50 ohm
C	Nonlinear load capacitance	65 uF
L	Active filter inductance	15mH
C_1	Active filter capacitance	1mF

V. SIMULATION RESULTS

The active power filter circuit using neural reference generator and linear reference generator are established in Matlab Simulink environment. Simulink model using neural network is shown in Fig. 6. The system parameters used in these simulations are provided in Table 1. A system with supply voltage 230 V, 50 Hz is used. The DC reference voltage is set at 350V. The filter inductor is 15mH and the DC bus capacitor is 1mF. This control system is able to detect and eliminate most of the harmonics present in the source current

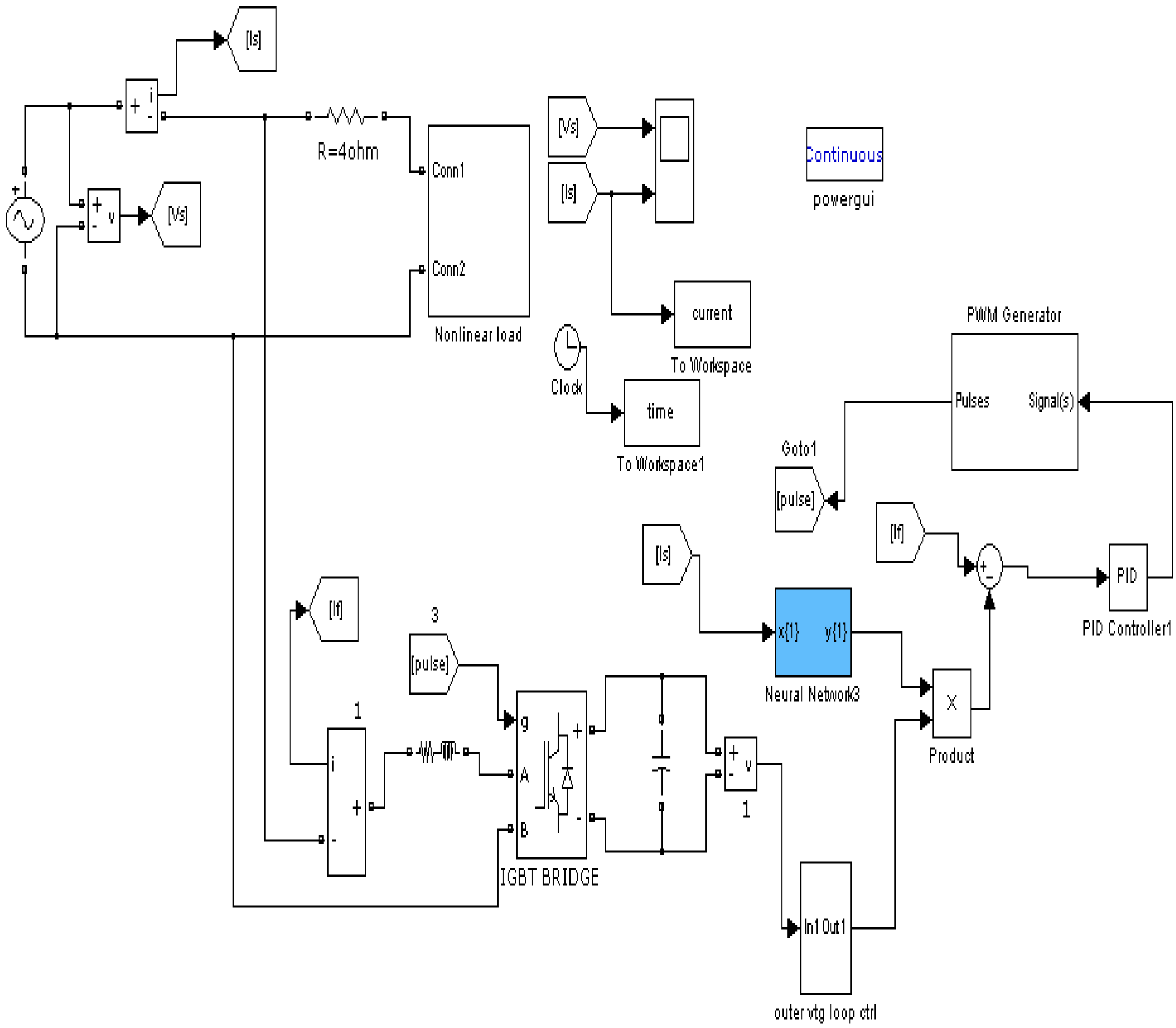

Fig. 6 simulation model of APF based on neural harmonic estimator

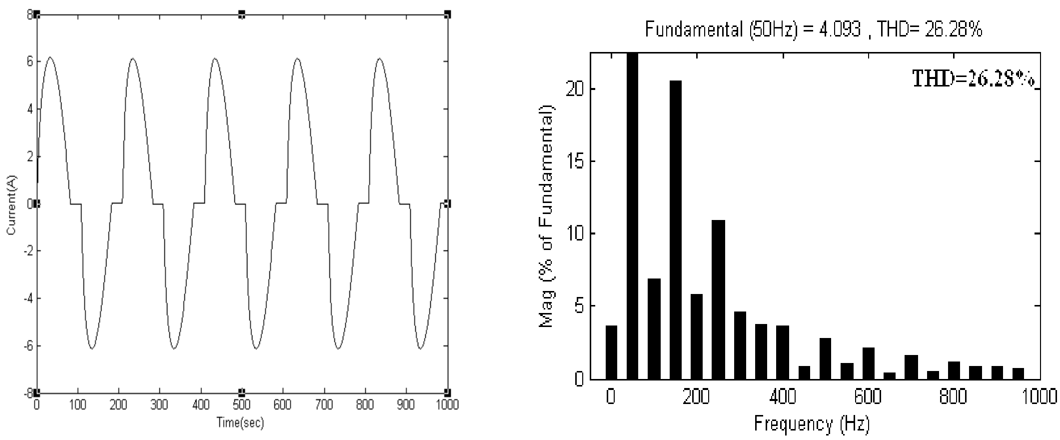

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Fig. 7 grid current waveform and FFT analysis without filter

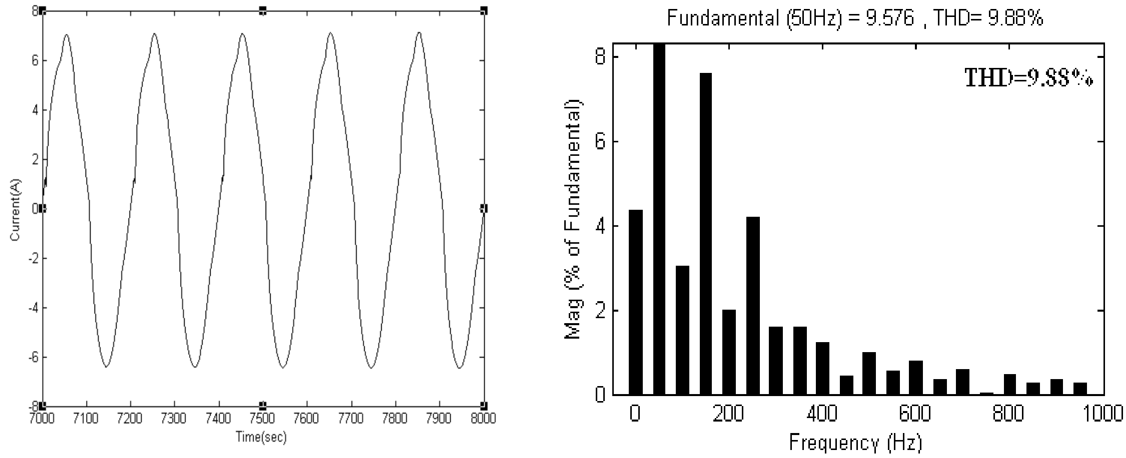

Fig. 8 Grid current waveform and FFT analysis with filter using linear reference generating control technique.

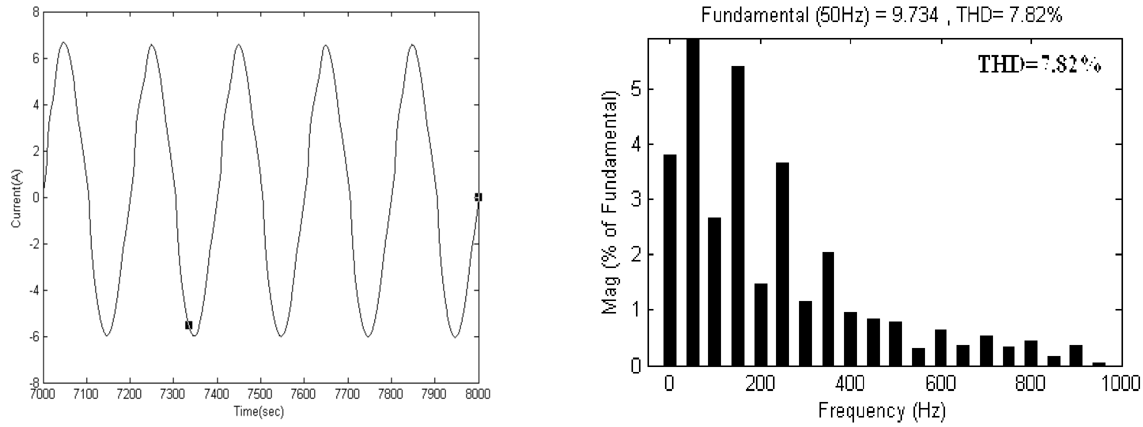

Fig.9 Grid current waveform and FFT analysis with filter using neural reference generator.

The nonlinear load consists of a series resistor R_s with an uncontrolled bridge rectifier connected to a capacitor C and a resistive load R. A proportional-integral (PI) voltage loop has been used to set the proper magnitude of the line current.

The proposed neural network based control strategy and linear controller have been tested in Matlab Simulink and results are compared. These results reveal, with the use of neural controller, the magnitude of the harmonic components is considerably reduced in the grid current. The proposed neural control system is able to detect the largest load harmonics and to compensate them properly. Fig. 7 shows the distorted current waveform when a nonlinear load is connected across the grid. Through the analysis of the waveforms given it is clear that THD of grid current 26.28% when load is connected. It is reduced to 9.88% by the use of APF with linear control scheme. It is shown in Fig 8. Fig 9 shows that the neural controller is able to reduce this harmonics further, to 7.82%. Compared to the linear controller proposed neural controller has the advantage of increased overall efficiency with its high learning rate. It can adapt itself to compensate for variations in nonlinear current or nonlinear loads. Higher order harmonics are attenuated very efficiently using neural controller.

VI. CONCLUSIONS

In this paper, an active power filter has been designed and the control methods have been presented. Proposed controller has been designed to mitigate the selective harmonic currents. The shunt active filter has been used to compensate a nonlinear load harmonic current. The filter's parameters are made adaptive versus the grid current fluctuations. The inverter of the shunt active filter is current controlled by a PI controller whose reference is given by a neural filter. Compared to linear current control scheme, neural controller has high attenuation against high order harmonics. In linear current control conventional PI control loop that regulates the average level of the filter capacitor voltage and a resonant selective harmonic compensator are used. This controller is compared with neural network which shows the better performance in compensation of current harmonics.

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