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Prototype of ANN Control Renewable Interfacing Inverter in 3P4W Distribution Network

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Abstract: ***Renewable vitality assets (RES) are as a rule progressively joined in conveyance frameworks using force electronic converters/inverters. This paper displays a Neural Network control system for the renewable interfacing inverter, it is a four leg inverter that is equipped for repaying uneven nonlinear burden at PCC, here the heap nonpartisan current is kept from streaming into the matrix side by remunerating it by regional standards from the fourth leg of the inverter. The fundamental goal of this task is to accomplish nonlinear lopsided burden remuneration and smooth bidirectional force stream all the while. It is a profoundly nonlinear framework such that the inverter works under very fluctuating working conditions, so the pi controller is unrealistic to situated the ideal addition values, which may prompt a bogus operation of the inverter. The consolidated capacity of Neural Network controller in taking care of the vulnerabilities and gaining from the procedures is turned out to be worthwhile while controlling the inverter under distinctive working conditions. The inverter is effectively controlled keeping in mind the end goal to remunerate the present sounds, responsive force, and the present unbalance of a three-stage four-wire nonlinear burden with produced renewable force infusion into the network all the while. This empowers the matrix to dependably retain/supply an adjusted arrangement of crucial streams at solidarity force figure even the vicinity of the nonlinear unequal burden at the purpose of normal coupling. The proposed framework is produced and recreated in MATLAB/SimPowerSystem environment under diverse working conditions.***

Keywords*:* Renewable energy, Distributed generation, grid interconnection, Neural Network control, nonlinear load, power quality

1. Introduction

Nowadays, fossil fuel is the main energy supplier of the worldwide economy, but it is recognised as a major cause of environmental problems makes the mankind to look for alternative resources in power generation. Moreover, the global increasing demand for energy which can create problems for the power distributors, like outages and grid instability. The necessity of producing more energy combined with the interest in clean technologies yields in an increased development of power distribution systems using renewable energy. Renewable energy sources (RES) integrated at distribution level is termed as Distributed Generation (DG), it also reduces the number of power lines and size that must be constructed. Basically, these technologies are based on notably advanced Power Electronics because all Distributed Energy Systems (DES) require Power electronic Converters, electronic control units, and interconnection techniques. That is, all power generated by DES is generated as DC Power, and then all the power fed to the DC distribution bus is again converted into an AC power with fixed magnitude and frequency. So improved power electronic technologies that permit grid interconnection of asynchronous generation sources are definitely required to support distributed generation resources. Distributed Generation Systems have mainly been used as a standby power source for critical businesses. The utility is concerned due to the high penetration level of intermittent RES in distribution systems as it may pose a threat to network in terms of stability, voltage regulation and power-quality (PQ) issues. Therefore, the DG systems are required to comply with strict technical and regulatory frameworks to ensure efficient operation of overall network. The main idea is the maximum utilization of inverter rating which is most of the time underutilized due to intermittent nature of RES [1]. This paper investigates that the grid-interfacing inverter can effectively be utilized to perform following important functions: 1) transfer of active power harvested from the renewable resources (wind, solar, etc.); 2) load reactive power demand support; 3) current harmonics compensation at Point of Common Coupling (PCC); and 4) current unbalance and neutral current compensation in case of 3-phase 4-wire system. With adequate control of grid-interfacing inverter, all the above objectives can be accomplished either individually or simultaneously. The DG systems are actively controlled with the improvement in power electronics and digital control technology, so the system is operated with improved PQ at PCC. However, the extensive use of power electronics converters/inverters and non-linear loads at PCC can generate harmonic currents, which can deteriorate the quality of power [2].
The basic block diagram of the proposed system is as shown in Fig. 1.

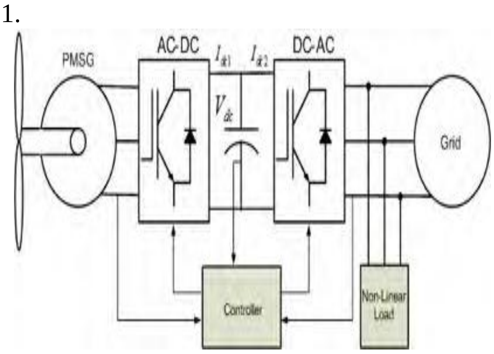


Figure 1: Basic block diagram of proposed system.

The proposed system employs PMSG based variable speed wind energy conversion system consisting two back to back converters. The generators side converter which is used to extract maximum amount of energy from the renewable energy systems , while grid side converters regulates dc-link voltage under fluctuating wind and grid disturbances. This paper is organized as follows: Section II presents the system control and configuration for the inverter. In Section III, presents the designing of Adaptive neuro Architecture controller. In Section IV, Simulation results are discussed and Section V finally concludes this paper.

2. Control and System Design

The control of inverter plays an important role in grid interconnection of renewable sources. In the present scenario, the RES are supposed to supply only active power, which may results in to increased grid pollution due to the non-linear unbalance load at PCC. However, with the advancement in power electronics and digital control technology, the RES can now be actively controlled to enhance the system stability with improved power quality at the point of common coupling (PCC). Recently a lot of control strategies for renewable interfacing inverter have been introduced [3]. The inverter operates as an active inductor at a certain frequency to absorb the harmonic current. But the calculation of network inductance in real time application is very difficult that can deteriorate the control performance. A similar approach in which shunt active filter acts as active conductance to damp out the harmonics in distribution network [4]. In both of these strategies, the load and inverter current sensing is required to compensate the load current harmonics. The current regulated voltage source inverters have very wide range of applications such as synchronization of RES to grid, UPS, static reactive power compensation (STATCOM), active power filters (APF) and adjustable speed drives (ASD). But in case of very first application, the installed inverter rating have very low utilization factor due to intermittent nature of RES [6]. The expected RES output during peak is nearly 60% of rated output, yet the annual capacity factor may be in the 20%-30% range. Therefore, the APF features have been incorporated in RES interfacing inverter to maximize its utilization without any additional hardware cost. Moreover, the proposed control strategy does not require the load current sensing. Therefore, only the grid current sensing is used for RES interfacing inverter. It further reduces the cost and complexity. The grid-interfacing inverter injects the generated active power from renewable as well as also compensates the load reactive power, current harmonics and load imbalance in a 3-phase 4-wire system [6]. This enables the grid to always supply a balanced set of sinusoidal currents at unity power factor (UPF). Since the inverter works under highly fluctuating operating conditions, the setting of optimal gain values for the conventional *PI* regulator is not possible [7]. This may lead to false operation of inverter. To overcome this problem an adaptive neuron Architecture controller is developed, which has well known advantages in modeling and control of a highly non-linear system. The main objective is to achieve non-linear unbalance load compensation and smooth bidirectional power simultaneously, where as the conventional proportional-integral (PI) controller may fail due to the rapid change in the dynamics of the highly non-linear system. The Neural Network controller have the combined capabilities in handling the uncertainties and learning from the processes is proved to be advantageous while controlling the inverter under fluctuating operating conditions.

2.1 System Configuration

The system under consideration with control description is shown in Fig. 2., where a RES is connected on the dc-link of grid interfacing 4-leg inverter. The fourth leg of inverter is utilized to compensate the neutral current of 3-phase 4-wire network. Here the inverter is a key element, since it delivers the power from renewable to grid and also solves the power quality problem arising due to unbalance non-linear load at PCC. The duty ratio of inverter switches are varied in a power cycle such that the combination of load and inverter injected power appears as balanced resistive load to the grid, resulting into the UPF grid operation. The renewable source may be a DC source or an AC source with rectifier coupled to dc link. The regulation of dc-link voltage carries the information regarding the exchange of active power in between renewable source and grid [8]. The error between reference dc-link voltage (*Vdc**) and actual dc-link voltage (*Vdc*) is given to the Neural Network controller and the same error is used to update the weights [9]. The output of Neural Network controller is further modified by subtracting the renewable injected current (I_{ren}). This results in to the reference d-axis current (*id**), while the reference q-axis current (*iq**) is set to zero for UPF grid operation. The grid synchronizing angle (θ) obtained from phase lock loop (PLL) is used to generate the reference grid currents (*ia**, *ib**, and *ic**). The reference grid neutral current (*in**) is set to zero to achieve balanced grid current operation. The hysteresis current controller is utilized to force the actual grid currents to track the reference grid currents accurately. This enables the grid to supply/absorb only the fundamental active power, thus the RES interfacing inverter fulfills the unbalance, reactive and non-linear current requirements of 3-phase 4-wire load at PCC.

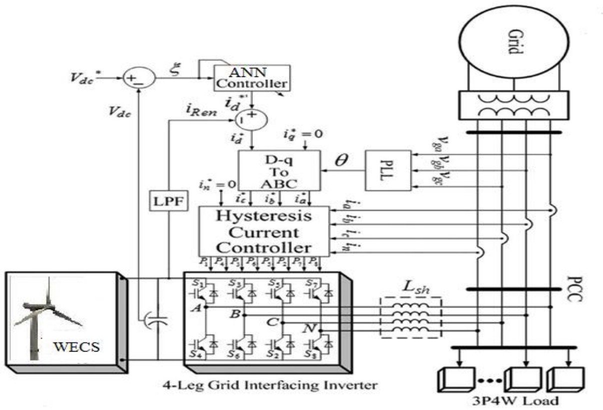


Figure 2: Proposed Renewable interfacing inverter

3. Design of Adaptive Neural Network Controller

Artificial neural network are simplified model of the biological neuron system. It is a extensively parallel circulated processing system made up of highly interconnected neural computing elements that have the ability to learn and thereby acquire knowledge. Their ease of use, inherent reliability and fault tolerance has made ANNs a viable medium for control.

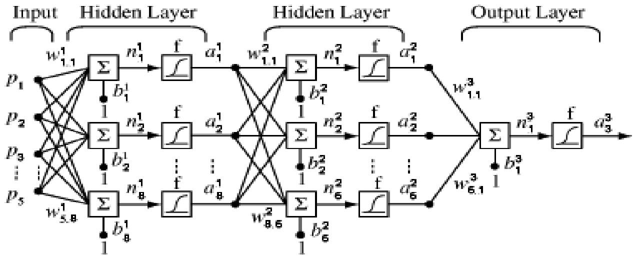


Figure 3(a): Basic Concept of ANN

.It possesses information in parallel at high speed. Most important advantage compared to other controllers is its adaptability to new situations and it is trained to new frequencies. Back propagation algorithm is used here for the training. Other controllers like PI PID and ANFIS Controllers need precise mathematical model for their analysis which is difficult to obtain under parameter variations and nonlinear load disturbances and another drawback of the system is that the proportional and integral gains are chosen using the input data. And the fuzzy controllers are based on rules and it is not adaptive to new situations. Typical artificial neural network includes three layers: input layer, hidden layer and output layer. Fig 3(a)&(b) shows an ANN with hidden layer.

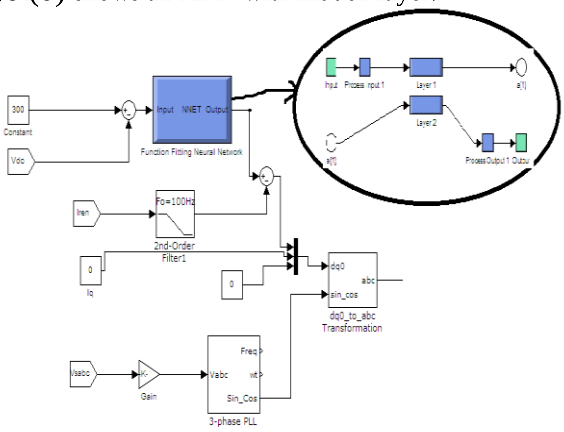


Figure 3(b): Schematic ANN Control Architecture

4. Simulation Results and Discussion

An extensive simulation study has been carried out for renewable interfacing inverter in order to verify the proposed control strategy. The system under consideration is simulated using the SimPowerSystem tool box of MATLAB/Simulink. An IGBT based 4-leg current controlled voltage source inverter is actively controlled to achieve the balanced sinusoidal grid currents at unity power factor (UPF) despite of highly unbalanced nonlinear load at PCC under varying renewable generating conditions.

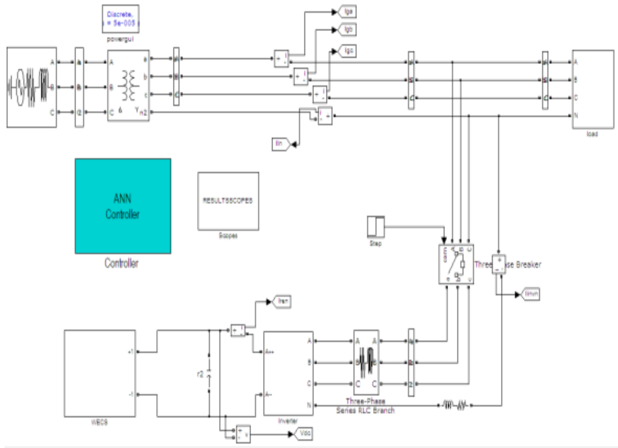
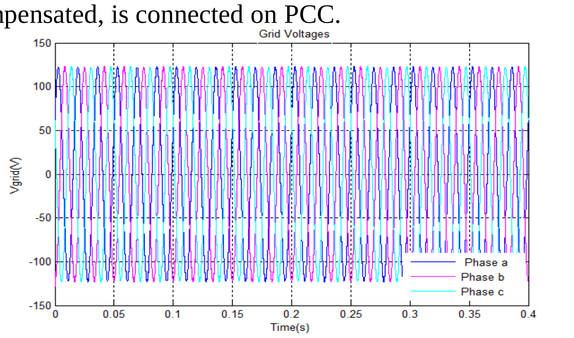
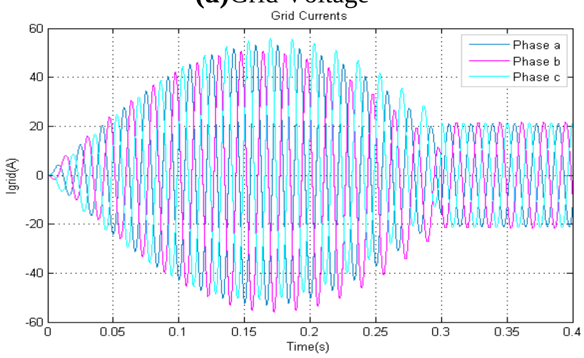


Figure 4: Simulink block diagram of renewable interfacing inverter.

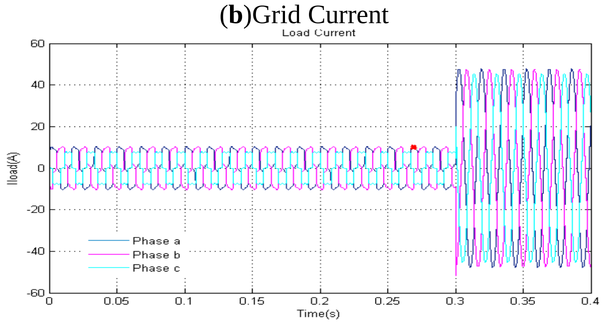
A renewable energy source with variable output power is connected on the dc-link of grid interfacing inverter. An unbalanced 3-phase 4-wire nonlinear variable load, whose harmonics, unbalance and reactive power are to be compensated, is connected on PCC.



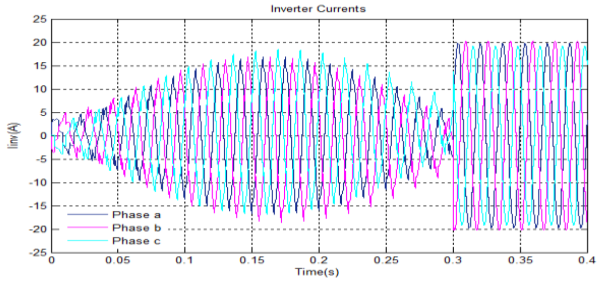
(a) Grid Voltage



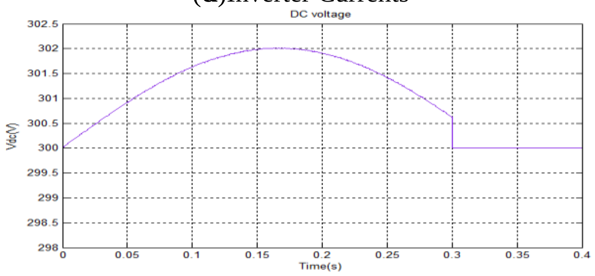
(**b**)Grid Current



(**c**)Unbalanced Load Currents



(**d**)Inverter Currents



(**e**)DC Link Voltage

Figure 5: Simulation results. (a) Grid voltages. (b) Grid currents. (c) Unbalanced load currents. (d) Inverter currents. (e) Dc link voltage

The main purpose of the proposed control strategy is to inject the generated renewable active power, load harmonics, and reactive power in such a way that only the injection/absorption of the active power takes place in the grid. Such a way that only the injection/absorption of the active power takes place in the grid. Initially, the generated active power is more than the load active power demand, so the extra generated power is being injected into the grid.

This fact can be verified from the traces of different currents, where the current supplied from the renewable is more than the load current, so the difference of these is being injected into the grid as evident from the out of- phase relation of the grid voltage (Vg) and grid current (Ig). In addition, the inverter is also supplying the harmonics, neutral current and reactive current component of the load current demand. This results into the perfectly balanced sinusoidal grid current even in the presence of a 3P4W unbalanced nonlinear load at PCC as shown in Fig.5. This fact can also be visualized from Figs6 and 7, where the phase *a* grid current (Iga) is purely sinusoidal and in phase opposition with the phase *a* grid voltage (Vga). Here, it can also be noticed that the load neutral current (Iln) is fully supplied by the inverter neutral current (Iinv). This results i the grid neutral current (Ign) as zero. At *t* = 0.3 s, there is a sudden increase in the load power demand, and the generated renewable active power is not sufficient enough to meet this demand. At this time instant, the renewable interfacing inverter supplies the generated active power and total load reactive power demand, while the grid supplies only the deficient amount of load active power. This fact can be verified from Figs. 6 and 7, where the phase *a* grid current, which was in the opposite phase to the grid voltage before *t* = 0.3 s, is now in phase with the grid voltage and the load neutral current is still being supplied from the inverter. Thus, from the simulation results, it is clear that the grid always works at UPF under fluctuating renewable power generation and dynamic load conditions with an unbalanced nonlinear load at PCC.

It can also be noticed that the dc-link voltage is almost constant at 300 V under both steady state and dynamic conditions, except negligible deviation due to a change in injected active power. Here, the dc-link voltage is shown on a very small scale, just to demonstrate the performance of the proposed ANN controller in controlling the dc-link voltage.

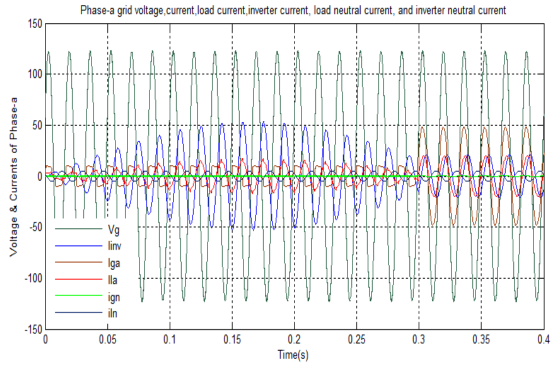
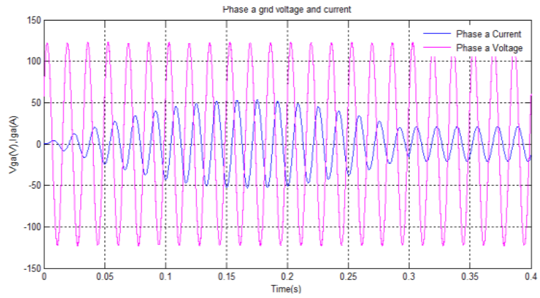
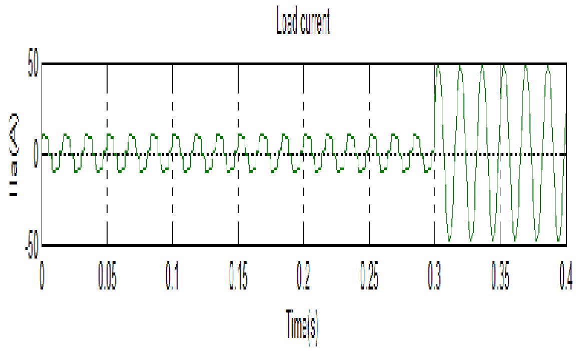


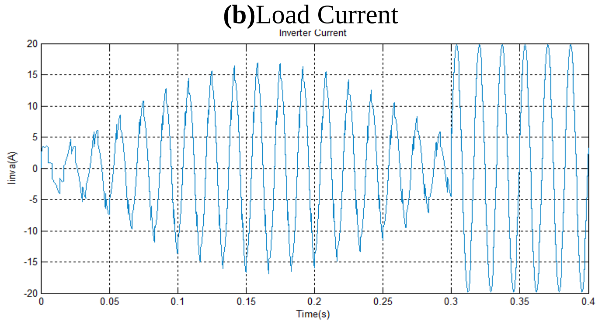
Figure 6: Simulation results: Phase *a* grid voltage, grid current, load current, inverter current, load neutral current, and inverter neutral current.



(a) Phase *a* grid voltage and current



(b) Load Current



(c) Inverter Current

Figure 7: Simulation results, Phase *a* grid voltage and current, Load Current, Inverter current

Before Compensation of Grid Current THD in %		After Compensation of Grid Current THD in %	
		ANFIS	ANN
AT TIME t=0.5 sec		t=0.35 sec	t=0.35 sec
i_a	19.88	3.19	2.34
i_b	24.49	3.29	2.37
i_c	30.70	3.39	2.45

5. Conclusion

This paper has presented a novel adaptive Neural Network control algorithm for controlling the renewable interfacing inverter. Such that it works satisfactorily under the dynamic operating conditions. It has also been shown that the inverter is able to perform all the duties of the shunt APF while maintaining the smooth bidirectional power flow simultaneously. The simulation results are provided to validate the fact that the renewable interfacing inverter can act as a multi operation device in order to utilize its maximum rating. The current unbalance, current harmonics, and load reactive power demand of an unbalanced nonlinear load at PCC are compensated effectively such that the grid side currents are always maintained as a balanced s of sinusoidal current at UPF. Moreover, the load neutral current is restricted to flow toward the grid side by supporting it locally from the fourth leg of the inverter. When the power generated from the renewable energy sources is more than the total load power demand, and then the grid-interfacing inverter with the proposed control approach successfully fulfils the total load demand (active, reactive, and harmonics) and delivers the remaining active power to the main grid at UPF operation.

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