ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Real Time Implementation of ANFIS Control for Renewable Source Connected To Distribution Grid

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Abstract:

This paper presents a novel adaptive neuro-fuzzy control approach for the renewable interfacing inverter. The main objective is to achieve smooth bidirectional power flow and nonlinear unbalanced load compensation simultaneously, where the conventional PI controller may fail due to the rapid change in dynamics of the highly nonlinear system. The combined capability of neuro-fuzzy controller is proved to be advantageous while controlling the inverter under fluctuating operating conditions. The inverter is actively controlled to compensate the harmonics, reactive power, and he current imbalance of a three-phase four-wire(3P4W) nonlinear load with generated renewable injection into the grid simultaneously. The proposed system is developed and simulated in MATLAB/SimPowerSystem environment.

Keywords:

Distributed generation, grid interconnection, neuro-fuzzy control, nonlinear load, power quality, renewable energy, unbalanced load

I. INTRODUCTION:

The increasing in global energy demand, air pollution, global warming and the rapid evaporation of fossil fuel has made it necessary to look toward renewable sources as a future energy solution. However, the high penetration level of these intermittent renewable energy sources (RESs) poses a great network security. Therefore, the RESs are required to comply with strict technical and regulatory frameworks to ensure the safe, reliable, and efficient operation of the overall network. With the advancement in power electronics and digital control technology, the RES can now be actively controlled to enhance the system stability with an improved power quality at the point of common coupling (PCC).

Recently, a lot of control strategies for renewable interfacing inverter have been introduced [1]–[7]. In [8], an inverter operates as an active inductor at a certain frequency to absorb the harmonic current. A similar approach in which a shunt active filter acts as an active conductance to damp out the harmonics in distribution network is proposed in [9]. In [10], a control strategy for renewable interfacing inverter based on p–q theory is proposed. A similar decoupled current control technique using PI regulator in d–q reference frame is presented in [11]. The current-regulated voltage source inverters have a very wide range of applications such as the grid synchronization of RES, static reactive power compensation, uninterruptible power supply, active power filters (APF), and adjustable speed drives. However, in the case of the very first application, the installed inverter rating has a very low utilization factor due to the intermittent nature of RES. According to [12] and [13], the expected RES output during peak is nearly 60% of the rated output, yet the annual capacity factor may be in the 20%–30% range. Therefore, the authors have incorporated the APF features in the RES interfacing inverter to maximize its utilization without any additional hardware cost.

Since the inverter works under highly fluctuating operating conditions, it is not possible to set the optimal value of gains for the conventional PI regulator [14]–[16]. This may lead to a false operation of the inverter. To alleviate this problem, an adaptive neuro-fuzzy controller is developed, which has well known advantages in modeling and control of a highly nonlinear system [17], [18]. An adaptive error backpropagation method is used to update the weights of the system for the fast convergence of control. This paper is organized as follows: Section II presents the system description and control algorithm for the inverter. In Section III, the simulation results are discussed, while the experimental results under different operating conditions are presented and discussed thoroughly in Section IV. Section V finally concludes this paper.

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II. SYSTEM CONFIGURATION AND CONTROL:

The system under consideration with control description is shown in Fig. 1, where a RES is connected on the dc link of a grid-interfacing four-leg inverter. The fourth leg of the inverter is utilized to compensate the neutral current of 3P4W 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 unbalanced nonlinear 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.

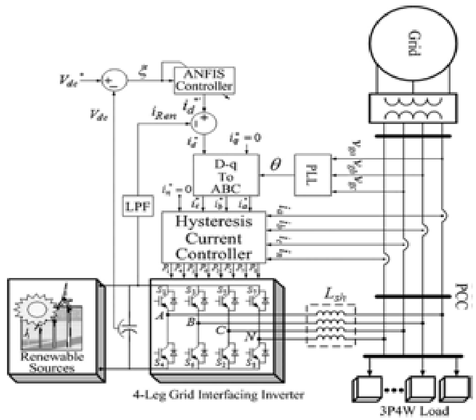

Fig. 1. Schematic and control description of proposed renewable-based distributed generation system.

The renewable source may be a dc source or an ac source with rectifier coupled to a dc link [19]. The regulation of dc-link voltage carries the information regarding the exchange of active power in between renewable source and grid. The error between reference dc-link voltage (V *dc) and actual dc-link voltage (Vdc) is given to the neuro-fuzzy controller, and the same error is used to update the weights. The output of neuro-fuzzy controller is further modified by subtracting the renewable injected current (iRen). This results into the reference d-axis current (i*d), while the reference q-axis current (i*q) is set to zero for UPF grid operation. The grid-synchronizing angle (θ) obtained from phase lock loop is used to generate the reference grid currents(i*a, i*b, and i*c). The reference grid neutral current i*n 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, while the RES-interfacing inverter fulfills the unbalance, reactive, and nonlinear current requirements of 3P4W load at PCC.

Design of Adaptive Neuro-Fuzzy Controller:

An optimized adaptive-network-based fuzzy inference system (ANFIS) having a 1:3:3:3:1 architecture is generated from the initial data using MATLAB/anfiseditor as shown in Fig. 2. This Takagi-Sugeno-Kang fuzzy model-based ANFIS architecture has one input and one output, which is further tuned online using the error backpropagation method as shown in Fig. 3. The error between reference .

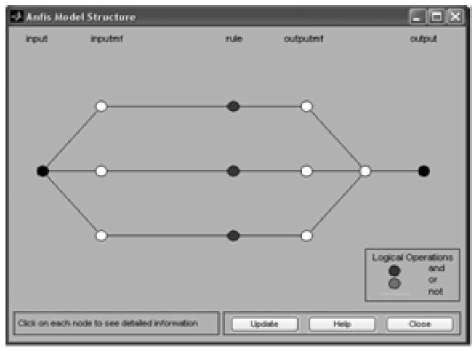

Fig. 2. Optimized ANFIS architecture suggested by MATLAB/anfiseditor.

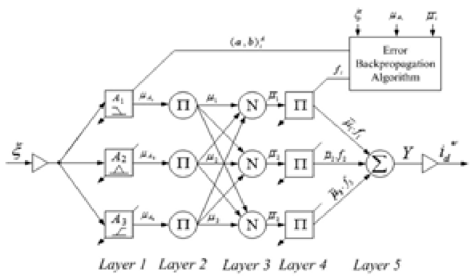

Fig. 3. Schematic of the proposed ANFIS-based control architecture.

dc-link voltage and actual dc-link voltage (ξ = V *dc− Vdc) is given to the neuro-fuzzy controller, and the same error is used to tune the precondition and consequent parameters. The control of dc-link voltage gives the active power current component (i*d), which is further modified to take into account the active current component injected from RES (iRen). The node functions of each layer in the ANFIS architecture are described as follows:

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Layer 1: This layer is also known as the fuzzification layer where each node is represented by a square. Here, three membership functions are assigned to each input. The trapezoidal and triangular membership functions are used to reduce the computation burden as shown in Fig. 4, and their corresponding node equations are given as follows:

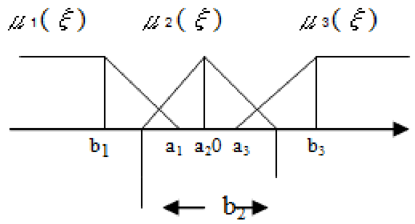

Fig. 4. Fuzzy membership functions.

$$\mu_{A1}(\xi)=\begin{cases}1 & \xi \le b1\\ \xi-a1/\,b1-a1 & b1\_\ \xi\_a1\\ 0 & \xi \ge a1\end{cases} \qquad (1)$$

$$\mu_{A2}(\xi)=\_1-\xi-a2/0.5b2/\ \xi-a2/\le 0.5b2$$

$$0\ /\ \xi-a2/\ge 0.5b2 \qquad (2)$$

$$\mu_{A3}(\xi)=\begin{cases}0 & \xi \le a3\\ \xi-a3/b3-a3 & a3\_\ \xi\_b3\\ 1 & \xi \ge b3\end{cases} \qquad (3)$$

where the value of the parameters {ai, bi} changes with the change in error and accordingly generates the linguistic value of each membership function. Parameters in this layer are referred as premise parameters or precondition parameters.

Layer 2: Every node in this layer is a circle labeled as Π which multiplies the incoming signals and forwards it to the next layer

$$\mu i = \mu Ai\ (\xi 1) \bullet \mu Bi\ (\xi 2) \bullet \bullet \bullet,\ i= 1, 2, 3. \quad (4)$$

However, in our case, there is only one input, so this layer can be ignored and the output of the first layer will directly pass to the third layer.Here, the output of each node represents the firing strength of a rule.

Layer 3: Every node in this layer is represented by a circle. This layer calculates the normalized firing strength of each rule as given in the following:

$$\mu i = \frac{\mu i}{\mu 1 + \mu 2 + \mu 3} \quad i= 1, 2, 3. \ (5)$$

Layer 4: Every node in this layer is a square node with a node function

$$Oi = \mu i \bullet fi = \mu i(a0i + a1i \bullet \xi),\ i= 1, 2, 3 \qquad (6)$$

where the parameters {a0i, a1i} are tuned as the function of the input (ξ). The parameters in this layer are also referred as consequent parameters.

Layer 5: This layer is also called the output layer which computes the output as given in the following:

$$Y = \mu 1 \bullet f1 + \mu 2 \bullet f2 + \mu 3 \bullet f3. \qquad (7)$$

The output from this layer is multiplied with the normalizing factor to obtain the active power current component (i*'d). The detailed algorithm for the training of the ANFIS architecture is given in Appendix II.

III. SIMULATION RESULTS AND DISCUSSION:

An extensive simulation study has been carried out for the 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 four-leg current-controlled voltage source inverter is actively controlled to achieve the balanced sinusoidal grid currents at UPF despite the highly unbalanced nonlinear load at the PCC under varying renewable generating conditions. A RES with variable output power is connected on the dc link of the grid-interfacing inverter. An unbalanced 3P4W nonlinear variable load, whose harmonics, unbalance, and reactive power are to be compensated, is connected on the PCC.

The waveforms of grid voltage (Vg), grid current (ig), unbalanced load current (il), injected inverter currents (iinv), and dc-link voltage (Vdc) are shown in Figure the traces of phase a grid current (iga), phase a load current (ila), and phase a inverter current (iinva) are shown w.r.t. phase a grid voltage (Vga). In addition, the waveforms of grid neutral current (ign), load neutral current (iln), and inverter neutral current (iinvn) are also shown in the same diagram. Fig. 7 shows the traces of phase a grid voltage (Vga) and phase a grid current (iga) on the same plot, phase a load current (ila), and phase a inverter current (iinva).

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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. 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 (Vga) and grid current (iga). In addition, the inverter is also supplying the harmonics, neutral current, and reactive current component of the load current demand. The Fig.5 shows the MATLAB/SIMULINK model of proposed system.

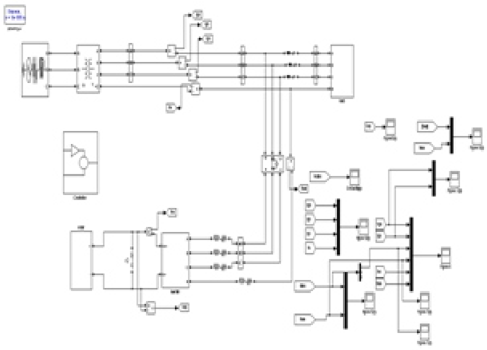


Fig. 5 simulink model of proposed system

This fact can also be visualized from Figs. 7 and 8, 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 (iinvn). This results into the zero value of the grid neutral current (in).

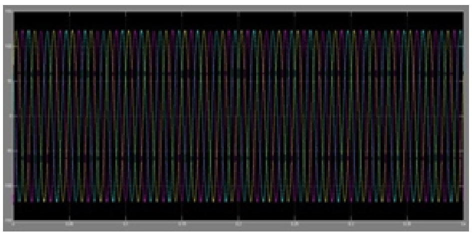
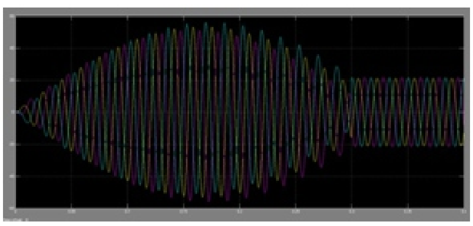


Fig. 5



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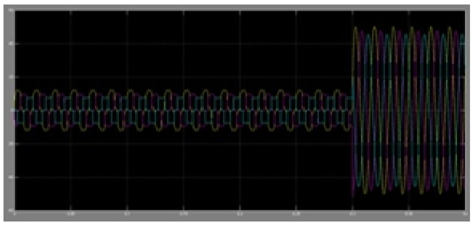

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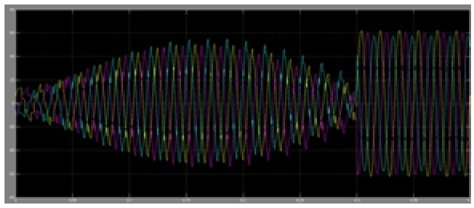

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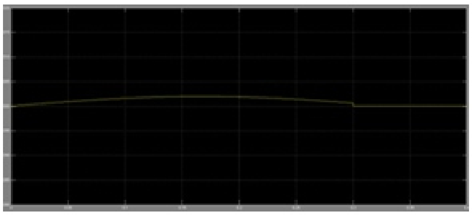

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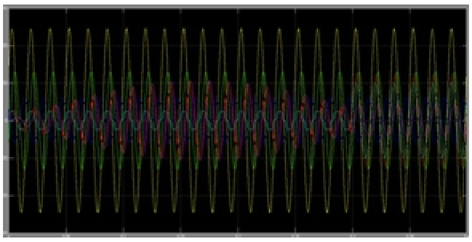

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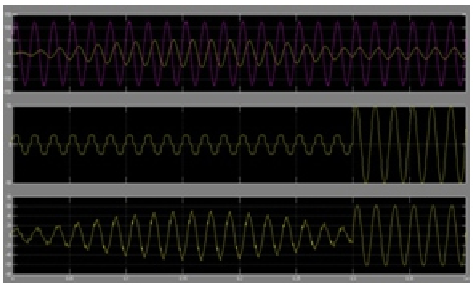

Fig. 5

V. CONCLUSION:

This paper has presented a novel adaptive neuro-fuzzy-control algorithm for the renewable interfacing inverter. The controller 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 supported by the experimental 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 set (0% UF) of sinusoidal current (2.7% THD) at UPF. Moreover, the load neutral current is restricted to flow toward the grid side (almost zero) by supporting it locally from the fourth leg of the inverter. When the power generated from the renewable is more than the total load power demand, the grid-interfacing inverter with the proposed control approach successfully fulfills the total load demand (active, reactive, and harmonics) and delivers the remaining active power to the main grid at UPF operation.

REFERENCES:

[1] M. Singh and A. Chandra, "Power maximization and voltage sag/swell ride-through capability of PMSG based variable speed wind energy conversion system," in Proc. 34th IEEE IECON/IECON, Orlando, FL, 2008.

[2] F. Blaabjerg, R. Teodorescu, M. Liserre, and A. V. Timbus, "Overview of control and grid synchronization for distributed power generation systems," IEEE Trans. Ind. Electron., vol. 53, no. 5, pp. 1398–1409, Oct. 2006.

[3] X. Guo, W. Wu, and Z. Chen, "Multiple-complex coefficient-filter-based phase-locked loop and synchronization technique for three-phase gridinterfaced converters in distributed utility networks," IEEE Trans. Ind. Electron., vol. 58, no. 4, pp. 1194–1204, Apr. 2011.

[4] P. Jintakosonwit, H. Akagi, H. Fujita, and S. Ogasawara, "Implementation and performance of automatic gain adjustment in a shunt-active filter for harmonic damping throughout a power distribution system," IEEE Trans. Power Electron., vol. 17, no. 3, pp. 438–447, May 2002.

[5] J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz, E. Galván,R. C. P. Guisado, M. Á. M. Prats, J. I. León, and N. Moreno Alfonso, "Power-electronic systems for the grid integration of renewable energy sources: A survey," IEEE Trans. Ind. Electron., vol. 53, no. 4, pp. 1002–1016, Jun. 2006.

[6] J. H. R. Enslin and P. J.M. Heskes, "Harmonic interaction between a large number of distributed power inverters and the distribution network," IEEE Trans. Power Electron., vol. 19, no. 6, pp. 1586–1593, Nov. 2004.

[7] M. Singh, V. Khadkikar, and A. Chandra, "Grid synchronization with harmonics and reactive power compensation capability of PMSG based variable speed wind energy conversion system," IET Trans. Power Electron., vol. 4, no. 1, pp. 122–130, Jan. 2011.

[8] U. Borup, F. Blaabjerg, and P. N. Enjeti, "Sharing of nonlinear load in parallel-connected three-phase converters," IEEE Trans. Ind. Appl., vol. 37, no. 6, pp. 1817–1823, Nov./Dec. 2001.

[9] P. Jintakosonwit, H. Fujita, H. Akagi, and S. Ogasawara, "Implementation and performance of cooperative control of shunt active filters for harmonic damping throughout a power distribution system," IEEE Trans. Ind. Appl., vol. 39, no. 2, pp. 556–564, Mar./Apr. 2003.

[10] J. P. Pinto, R. Pregitzer, L. F. C. Monteiro, and J. L. Afonso, "3-phase 4-wire shunt active power filter with renewable energy interface," in Proc. IEEE ICREPQ Conf., Seville, Spain, 2007.

[11] S. Rahmani, A. Hamadi, N.Mendalek, and K. Al-Haddad, "A new control technique for three-phase shunt hybrid power filter," IEEE Trans. Ind. Electron., vol. 56, no. 8, pp. 2904–2915, Aug. 2009.

[12] N. Boccard, "Capacity factor of wind power realized values vs. estimates," Elsevier Trans. Energy Policy, vol. 37, no. 7, pp. 2679–2688, Jul. 2009.

[13] Capacity Factors at Kansas Wind Farms Compared With Total State Electrical Demand, July 2007 to June 2008. [Online].

[14] L. Yacoubi, K. Al-Haddad, L. A. Dessaint, and F. Fnaiech, "Linear and nonlinear control techniques for a three-phase three-level NPC boost rectifier," IEEE Trans. Ind. Electron., vol. 53, no. 6, pp. 1908–1918, Dec. 2006.

[15] S. Yang, Q. Lei, F. Z. Peng, and Z. Qian, "A robust control scheme for grid-connected voltage-source inverters," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 202–212, Jan. 2011.

[16] J. M. Espí, J. Castelló, R. García-Gil, G. Garcerá, and E. Figueres, "An adaptive robust predictive current control for three-phase grid-connected inverters," IEEE Trans. Ind. Electron., vol. 58, no. 8, pp. 3537–3546,Aug. 2011.

[17] H. Li, K. L. Shi, and P. G. McLaren, "Neural-network-based sensor less maximum wind energy capture with compensated power coefficient," IEEE Trans. Ind. Appl., vol. 41, no. 6, pp. 1548–1556, Nov./Dec. 2005.

[18] J.-S. R. Jang, "ANFIS: Adaptive-network-based fuzzy inference system," IEEE Trans. Syst. Man, Cybern., vol. 23, no. 3, pp. 665–685,May/Jun. 1993

[19] E. C. dos Santos, Jr., C. B. Jacobean, G. A. de Almeida Carlos, andI. S. de Freitas, "Component minimized AC–DC–AC single-phase to three-phase four-wire converters," IEEE Trans. Ind. Electron., vol. 58, no. 10, pp. 4624–4635, Oct. 2011.

[20] B. K. Bose, Modern Power Electronics and AC Drives. Upper Saddle River, NJ: Prentice Hall, 2002.

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