Implementation of Grid Based Distributed 3P4W System Using ANFIS Control

P.Jeevanateja, M. Sridhar,
M.Tech., scholar, Head of the Dept.EEE
Department of Electrical & Electronics Engineering
Godavari Institute of Engineering & Technology, 533296, Rajahmundry, A.P, India

ABSTRACT:

The increase in global energy demand and load demand, the Renewable Energy Sources (RES) are increasingly connected in the distribution systems which utilises power electronics Converters/Inverters. This paper suggests a new method that consists of a four leg inverter that is capable of simultaneously compensating problems like current imbalance and current harmonics, reactive power demand, power factor and also injecting the energy generated by renewable energy sources. Thus the load neutral current is prevented from flowing into the grid side by compensating it locally from the fourth leg of the inverter. The main objective of this project is nonlinear unbalanced load compensation. Since the inverter works under highly fluctuating operating conditions, it is not possible to set optimal values of gains for the PI controller, this may lead to a false operation of the inverter. Since This paper presents a novel control strategy for renewable interfacing inverter to achieve nonlinear unbalanced load at PCC. Adaptive neuro-fuzzy control is used to overcome all types of nonlinear loads at PCC to make the load to be linear to the grid. This enables the grid to always supply/absorb a balanced set of fundamental currents at unity power factor even in the presence of the 3P4W nonlinear unbalanced load at the point of common coupling. This work is carried out and simulated in MATLAB/SimPowerSystem environment under different operating conditions.

INDEX TERMS --Non linear load, grid interfacing inverter, Shunt Active Power Filter, Power Quality, neuro-fuzzy control, renewable energy source, distribution generation and unbalanced load

INTRODUCTION:

There is growing interest in renewable energy around the world. Since most renewable sources are intermittent in nature, it is a challenging task to integrate renewable energy resources into the power grid infrastructure. In this grid integration, communication systems are crucial technologies, which enable the accommodation of distributed renewable energy generation and play an extremely important role in monitoring, operating, and protecting both renewable energy generators and power systems. Due to presence of the nonlinear devices disturbances are occurred on the electrical network, due to these disturbances harmonics are produced, which effects the sensitive equipment of power system. These harmonics in the power system are eliminated with the use of active power filters. So active power line conditioners have become popular than passive filters as it compensates the harmonics and reactive power simultaneously. The active power filter topology can be connected in series or shunt and combinations of both. Shunt active filter is more popular than series active filter because most of the industrial applications require current harmonics compensation [2].

Micro-grids can generally be viewed as a cluster of micro generator connected to the mains utility grid, usually through some voltage source inverter (VSI) based interfaces [4]. Concerning the interfacing of a micro-grid to the utility system, an important area of study is to investigate the impact of unbalanced utility grid voltages (usually caused by unbalanced system faults or connected loads) on the overall system performance. As a common practice, if the utility grid voltages are seriously unbalanced, a separation device, connected between the micro-grid and mains-grid to provide isolation in the event of mains faults, will open and isolate the micro-grid. But when the utility voltages are not so seriously unbalanced, the separation device will remain closed, subjecting the micro-grid to sustained unbalanced voltages at the point of common coupling (PCC), if no compensating action is taken. Such an unbalance in voltages can cause increased losses in motor loads and abnormal operation of sensitive equipment. An obvious solution is to balance the voltages within the micro-grid using some voltage regulation techniques. However large unbalanced currents can flow...
The proposed system consists of RES connected to the dc-link of a grid-interfacing inverter as shown in Fig. 1. As voltage source inverter interfaces the renewable energy source to the grid and delivers the generated power, it is considered as a key element of DG system. The RES may be a DC source or an AC source with rectifier coupled to dc-link. The power generated from these renewable sources need power conditioning before connecting to dc-link. The dc-capacitor allows independent control of converters on either side of dc-link and decouples the RES from the grid.

The output of neuro-fuzzy controller is further modified by subtracting the renewable injected current \( i_{\text{ren}} \). 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 \( \theta \) 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 fulfils the unbalance, reactive, and nonlinear current requirements of 3P4W load at PCC.

![Fig.2. Block diagram representation of hysteresis current controller](image)

**Design of adaptive neuro-fuzzy controller:**

Adaptive neuro fuzzy inference system (ANFIS) integrates the best features of fuzzy systems and neural networks, and it has potential to capture the benefits of both in a single framework. ANFIS is a kind of artificial neural network that is based on Takagi-sugeno fuzzy inference system, which is having one input and one output. Using a given input/output data set, the toolbox function ANFIS constructs a fuzzy inference system (FIS) whose membership function parameters are tuned (adjusted) using a back propagation algorithm. Fig. 3 shows schematic of the proposed ANFIS based control architecture. The node functions of each layer in the ANFIS architecture are described as follows:

**Layer 1:** In this layer each node is represented by a square. This layer is known as Fuzzification layer. In this layer membership functions are assigned to each input. The trapezoidal and triangular membership functions are used to reduce the computation and their corresponding node equations are given as follows:

\[
\mu_{A_i}(\xi) = \begin{cases} 
1 & \xi \leq a_1 \\
\frac{\xi - a_1}{a_2 - a_1} & a_1 < \xi < a_2 \\
0 & \xi \geq a_2 
\end{cases}
\]

(1) \(\mu_{A_2}(\xi) = \begin{cases} 
1 & |\xi - a_1| \leq 0.5b_1 \\
0 & |\xi - a_1| > 0.5b_1 
\end{cases}\) (2)

\[
\mu_{A_3}(\xi) = \begin{cases} 
1 & \xi \leq b_3 \\
0 & \xi > b_3 
\end{cases}
\]

Where the value of the parameters \((a_1, b_1)\) 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 labelled as which multiplies the incoming signals and forwards it to the next layer.

\[
\mu_i = \mu_i(\xi_1, \mu_i(\xi_1, \xi_2), \ldots, i = 1, 2, \ldots, (4)
\]

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 circle. This layer calculates the normalized firing strength of each rule as given in the following:

\[
\overline{\mu_i} = \frac{\mu_i}{\mu_1 + \mu_2 + \mu_3}, i = 1, 2, 3, (5)
\]

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

\[
O_i = \bar{O}_i = \bar{O}_i(a_0^i + a_1^i \xi), i = 1, 2, 3, (6)
\]

Where the parameters \((a_0^i, a_1^i)\) are tuned as the function of the input \((\xi)\). 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:

\[
Y = \frac{\overline{\mu_i}}{\overline{\mu_1} + \overline{\mu_2} + \overline{\mu_3}} \cdot f_i = f_1 + f_2 + f_3, (7)
\]

III. SIMULATION RESULT AND
DISCUSSION

To verify the proposed control strategy, an extensive simulation strategy is carried out using MATLAB/Simulink. The 4-leg grid interfacing inverter is actively controlled under varying renewable generating condition in order to achieve balanced sinusoidal grid currents at unity power factor. 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 \( V_g \), grid current \( i_g \), unbalanced load current \( i_l \), injected inverter currents \( i_{inv} \), are shown in the fig.5. In Fig. 6, the traces of phase \( a \) grid current \( i_{ga} \), phase \( a \) load current \( i_{la} \), and phase \( a \) inverter current \( i_{ina} \) are shown w.r.t. phase \( a \) grid voltage \( V_{ga} \). In addition, the waveforms of grid neutral current \( i_{gn} \), load neutral current \( i_{ln} \), and inverter neutral current \( i_{inn} \) are also shown in the same diagram. Fig. 7 shows the traces of phase \( a \) grid voltage \( V_{ga} \) and phase \( a \) grid current \( i_{ga} \) on the same plot, phase \( a \) load current \( i_{la} \), and phase \( a \) inverter current \( i_{ina} \).

![Fig. 5. Simulation results: (a) grid currents, (b) grid voltages, (c) load currents, (d) inverter currents.](image)

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 \( V_g \) and grid current \( i_g \). 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 Figs. 6 and 7, where the phase \( a \) grid current \( i_{ga} \) is purely sinusoidal and in phase opposition with the phase \( a \) grid voltage \( V_{ga} \). Here, it can also be noticed that the load neutral current \( i_{ln} \) is fully supplied by the inverter neutral current \( i_{inn} \). This results into the zero value of the grid neutral current \( i_n \). At time \( t = 0.375 \) s, there is a sudden increase in the load power demand, and the generated renewable active power is not sufficient enough to meet this enhanced demand. At this 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 \( t = 0.375 \) 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 ANFIS controller in controlling the dc-link voltage.
IV. EXPERIMENTAL RESULT AND DISCUSSION

The proposed adaptive neuro-fuzzy controller is implemented in real time on a four-leg IGBT-based inverter using digital signal processing and control engineering DS1104, whereas the RES is emulated with an auxiliary inverter connected on a dc link. It takes a sampling time of 75 μs to realize the proposed ANFIS controller in real time. The 3P4W nonlinear load is composed of three-phase nonlinear RL load, one-phase RL nonlinear load connected in between phase a and neutral, and a single-phase RL load in between phase b and neutral.

An extensive experimental study is carried out to highlight the performance of the inverter as a multiobjective device. The inverter operation is mainly divided into two parts: active filter operation and renewable interfacing operation. All the experimental results are captured with an oscilloscope in real time as shown in Figs. 8–10.

A. Active Filter Operation:

In this mode of operation, only the active filtering capabilities of the inverter are demonstrated. In Fig. 8(a), the traces of 3P4W grid currents are shown before and after compensation. Initially, the grid supplies an unbalanced nonlinear load current with a high neutral current, which is highly undesirable. In order to compensate this unbalanced nonlinear current, the inverter currents are injected in such a way that the combination of load and inverter current appears as a balanced set of fundamental currents. The traces of the injected inverter currents are shown in Fig. 8(b), just before and after compensation. Here, it can be easily noticed that the grid currents are perfectly balanced with a sinusoidal profile. Moreover, the inverter is successfully able to supply the load neutral current demand locally, as evident from the zero value of the grid neutral current ($i_{gn}$).
TABLE I:
INVERTER PERFORMANCE AS A COMPENSATING DEVICE

<table>
<thead>
<tr>
<th>Grid Currents</th>
<th>Before Compensation</th>
<th>After Compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current (r.m.s.)</td>
<td>% THD</td>
</tr>
<tr>
<td>Phase-A</td>
<td>2.96</td>
<td>14.7</td>
</tr>
<tr>
<td>Phase-B</td>
<td>2.47</td>
<td>18.2</td>
</tr>
<tr>
<td>Phase-C</td>
<td>1.94</td>
<td>23.2</td>
</tr>
<tr>
<td>Neutral</td>
<td>1.1</td>
<td></td>
</tr>
</tbody>
</table>

RESULT:

The simulation result indicates the grid currents starts changing to sinusoidal balanced from unbalanced non-linear currents. It is also observed that the proposed method has improved significantly in terms of supply/absorb a balanced set of fundamental currents at UPF.

V. CONCLUSION

This project presented a control of an Three phase Four leg grid interfacing inverter improve the quality of power at PCC for a 3 phase 4 wire system. 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. This approach thus eliminates the need for additional power conditioning equipment to improve the quality of power at PCC. Thus the load neutral current is prevented from flowing into the grid side by compensating it locally from the fourth leg of the inverter.

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. 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 fulfils the total load demand (active, reactive, and harmonics) and delivers the remaining active power to the main grid at UPF operation.

REFERENCES:


