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POWER QUALITY ENHANCEMENT IN A SOLAR PV PLANT INTEGRATED UTILITY GRID BY USING RECURRENT NEURAL NETWORK

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Abstract— Harmonics are produced when solar PV systems are incorporated into distribution networks that employ several power processing units. These harmonics may cause sensitive equipment connected to the connection point to malfunction. Grid-connected voltage source inverters go around this restriction by using an exclusive adaptive current controller. To reach a high voltage level on a shared DC bus, a high-gain DC/DC converter with a Kalman-based maximum power point tracking method is also envisioned. A recurrent neural network trained using Hebb's least mean square weight update approach is used to create the suggested adaptive current controller in order to construct the three-phase reference currents. The system's harmonic emissions are decreased since they provide the necessary three-phase transient currents. Over the conventional PI controller, the suggested method offers a variety of benefits, including greater stability, quicker settling times, adaptive behaviour, and more harmonic dampening abilities. A 50KW fuel cell is also included into the system to boost performance. The suggested current controller is used to assess system performance using MATLAB/Simulink.

Index Terms— “Hebbian least mean square (LMS), high-gain converter, Kalman-based maximum power point tracking (MPPT), power quality, proportional–integral, photovoltaic (PV) system, recurrent neural network (RNN), fuel cells”.

1. INTRODUCTION

To satisfy the predicted increases in energy consumption, renewable energy must be included into the current supply system. We can lessen our dependency on fossil fuels and save the environment from greenhouse gas emissions by deploying RES broadly. Studies that concentrate on the administration and operation of RES as well as their integration into the electrical grid are sparked by these considerations [1]. The production of electricity using photovoltaic (PV) technology is currently the most efficient renewable energy source [2]. Low output voltages, trouble monitoring the maximum power point (MPP) as a result of irregular solar radiation, and poor power quality as a result of the system's power electronic converters and fluctuating related loads are some of its other drawbacks. [3]–[5]. DC-DC step-up converters are used at the common intermediate circuit terminals to adapt to the low voltages of the PV system. The maximal diode reverse current, high power consumption during switching, and unexpected spikes in input current are drawbacks of conventional DC/DC converters [6]. In DC microgrids using traditional converters, this leads to low efficiency, significant losses, and excessive loads [7, 8]. An study of renewable energy sources that takes into account the power quality needed for FACTS devices was published by Ghiasi [34]. Also provided is a technique for supplying changing power quality in grid-connected renewable energy systems via optimization. Liu et al. suggested a transformer-based filter design in their publications [35] and [36] for enhancing and preserving power quality in DC source systems of industrial applications and PV power plants. Additionally, the electromagnetic decoupling model of the transformer-based filter design and the weak coupling and weak residual coupling of the integrated chokes on the performance of the filter are explored. High-gain, high-efficiency power processing units are used in microgrid systems to get around the problems that arise with conventional converters. This research presents a novel design for high-gain, more effective power processing units. It consists of storage capacitors, a Kalman MPPT, a passive clamp circuit, and other components interspersed with auxiliary inductors in various patterns. The low voltage level of the PV system is increased by this high-gain converter even with a brief duty cycle and little loss. Renewable energy must be used in the electrical system if greenhouse gas emissions are to be kept to a minimum [10]. For PV power conversion, it's also crucial to improve power quality by reducing voltage and frequency oscillations.

As a result, grid-tied converter operation demands accuracy and quick control. A filter circuit is also necessary to decrease the harmonics that power electronic components create [11], [12]. However, instability issues are brought on by filter circuits. Consequently, it is challenging to use a voltage source inverter (VSI) [13]. The current controller has an inconsistent and unexpected impact when regulating a grid-connected VSI [14]. Performance-based dual-loop control, also referred to as voltage and current control loops, has replaced the grid-connected systems' traditional single-loop control. A grid-tied system's ability to tolerate the calibre of energy supplied to the grid is determined by the power loop [15]. PI current controllers may be used with grid-connected inverters to adjust the output current to match a certain reference current that is determined by the needed power output to the utility grid, according to published research [16]. A PI current controller's key drawback is that it cannot function properly in imbalanced circumstances. A PI current controller often fails to follow a sinusoidal reference without steady-state error. Recurrent neural network (RNN) technology has been utilised to improve the control of reactive electricity injected into the grid and lessen the generation of harmonics in the system [17]. RNN outperforms conventional control systems in noisy environments and is self-adaptive to changes in system parameters, making it a superior control method. Additionally, it performs better when load fluctuations are significant [18]. The performance of the suggested RNN current controller is significantly influenced by the choice of an efficient training method. In order to enhance grid-tied VSI performance under various operating situations, this study intends to create a novel [Hebbian LMS-based RNN] adaptive current controller. The neurons of the RNN current regulator are trained via Hebbian LMS. RNN networks are created to automatically adapt to various operating situations using a unique unsupervised learning method [19]–[25]. The fundamental system elements, the control mechanism, stability analysis, and experimental validation are all covered in this article. The following is a description of the planned study's primary original scientific contributions. 1) Three-phase reference currents are generated using an adaptive RNN trained utilising a Hebbian LMS weight update approach in order to provide the necessary pulse width modulation signals for the grid-tied inverter. The PV system's power quality is enhanced as a result. 2) To obtain the necessary voltage level at the DC-Link bus terminals, a unique high-gain DC-DC boost converter with a Kalman-based MPP tracking algorithm (MPPT) is built. 3) A comparison between the proposed current controller and the conventional PI controller is done to demonstrate the efficacy of the suggested technique in various transient scenarios. 4) To demonstrate the superior stability of the suggested scheme for a grid-tied PV system, a control stability analysis of the proposed current controller is carried out utilising simulation and experimental platforms under various kinds of transient situations.

2. SYSTEM CONFIGURATION

Figure 3.2 displays the suggested innovation control technique coupled with the superior power production and transmission capabilities provided by an on-grid solar PV system. (a) The section that follows explores the design pillars of this control approach in greater depth. Regarding modelling and design considerations for solar PV systems, the work in [26] is assessed. When constructing the suggested system, a high gain, high efficiency DC/DC converter should be used to link the solar array to a common DC bus. In comparison to earlier models, this kind of converter increases voltage levels and efficiency while lowering switching and loading losses. The Kalman MPPT control method makes it simpler to govern a higher-gain, more effective converter [27]. The line-side converter is managed using dual loop power flow technology, also known as VSI. The power flow control approach typically comprises of an outer voltage loop to maintain a steady voltage level at the VSI's input and an inside current loop to enhance the power quality of the main currents. The Hebbian-LMS-trained RNN controller utilised in the paper also suggests a novel inner-loop control strategy. The VSI is also connected to the mains via step-up transformers and LC filters.

2.1 PROPOSED CONTROL STRATEGY

A. Kalman MPPT Algorithm, Section A Using the Kalman MPPT control method, switching pulses needed for high-gain, high-efficiency dc-dc converters are generated. State-space equations are used to represent the system for Kalman MPPT implementation. The following symbols are used to signify a system's state-space representation [27]:

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$$x(k+1) = Ax(k) + Bu(k) + Gw(k)$$

$$z(k) = Cx(k) + V(k)$$

where the state is x(k), the input is u(k), the output is z(k), the process noise is w(k), and the measurement noise is v(k). The real voltage is estimated using time update and measurement correction, as shown below: Update on measurements (correct)

$$K_{[k]} = H_{[k]^-} - [H_{[k]^-} + R]^{-1} \qquad (3)$$

$$\hat{V}_{\text{act}[k]} = \hat{V}_{\text{act}[k]^-} + K_{[k]}[V_{\text{ref}[k]} - \hat{V}_{\text{act}[k]^-}] \qquad (4)$$

$$H_{[k]} = [1 - K_{[k]}]H_{[k]^-}. \qquad (5)$$

Time update (predict)

$$\hat{V}_{\text{act}[k+1]} = \hat{V}_{\text{act}[k]} + M\frac{P_{[k]} - P_{[k-1]}}{V_{[k]} - V_{[k-1]}}$$

$$H_{[k+1]^-} = H_{[k]} + Q.$$

The Kalman gain K[k] must first be derived from (3). The next step included calculating the actual voltage V act[k] and error.

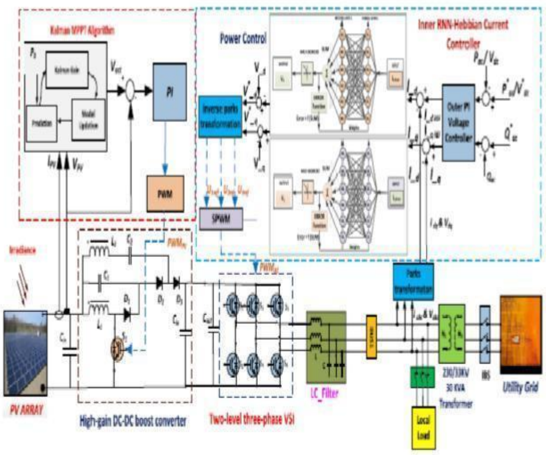

Fig 2.1 : Solar system linked to the grid using a new adaptive current regulator

Update Covariance Hk in accordance with (4) and (5). It is crucial to calculate the voltage V law[k+1] and the error covariance H[k+1] in the time update to make use of the data from (6) and (7). (7). It is anticipated that a voltage larger than V act[k] will approach the MPP. The actual value is set closer to MPP than V law[k], where Q is the plant's process noise, R is the measurement noise's covariance, and M is the phase. Since the anticipated voltage is V law[k+1], the actual value is set closer to MPP than V law[k]. The terminal voltage and currents are inputs into the Kalman algorithm, which computes the voltage in the next step. As shown in Fig. 4.1, the PI controller sends pulses to the DC/DC converter switch based on the voltage difference between the expected and actual voltage.

2.2.Neural-networks

"Neural networks" is one of the buzzwords of the contemporary technological age. Though many have heard of them, only a small number of people fully understand what they are. You will learn about all the fundamentals of neural networks in this essay, including their function, overall structure, terminology, kinds, and applications.

What we refer to as "neural networks" is really referred to as "artificial neural networks" since "neural network" is a biological word (ANNs). I will, however, go back and forth between the two concepts throughout the piece. A genuine neural network is made up of the small neurons that make up our brain. A network is made up of a few hundred million to several billion neurons that are interconnected in different ways. ANNs make an effort to mimic the structure and operation of these biological systems. One minor issue arises: we are unsure about the functioning of biological NNs. As a consequence, different kinds of neural networks have distinctive structural features. What we know is the basic structure of a neuron.

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3. results

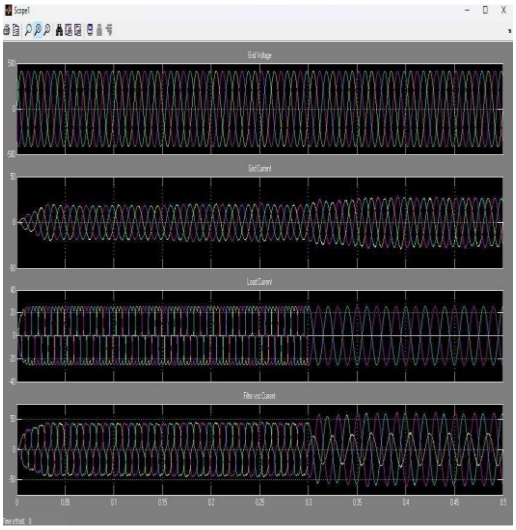

Fig 5.1(a) waveforms of grid voltage, grid current, load current and filter Vsc current

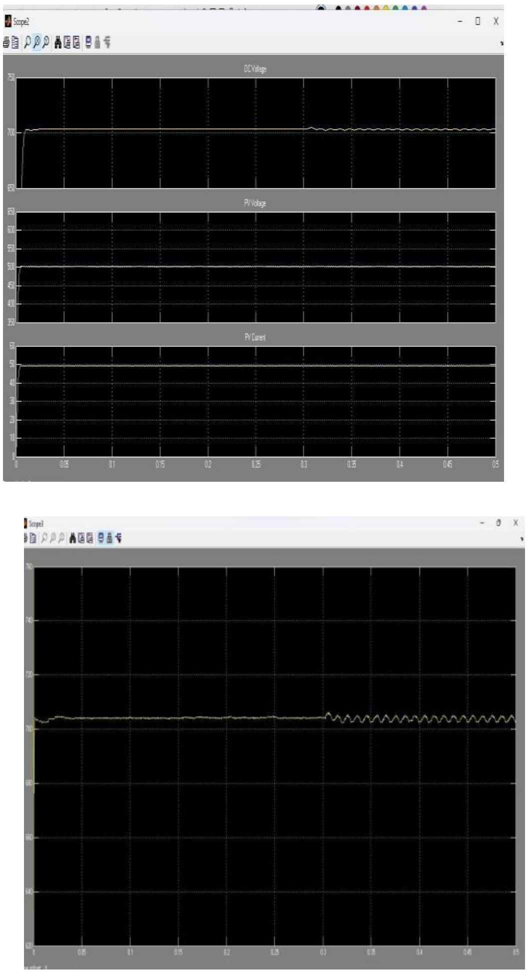

Fig 5.1(b) waveforms of DC voltage ,PV voltage, PV current

The Simulation Results Show That Addition Of Fuel Cells Into The Proposed Configuration Boosts The Performance Of The System As It Injects 50kw Power To The Grid Irrespective Of The Solsr System To Over Come The Disadvantages Of Solar Like Radiation And Temperature Effects This Minimizes The Current Requirements From The Grid By 50kw The Current Controller Is Designed Using RNN And Simulated Performance Is Shown

5. CONCLUSION

Renewable PV generation has been evolving as the best energy source in present power market scenario. PV plant integration to the utility grid is limited by some demerits like low PV terminal voltages and reduced power quality under dynamic load changes. In this view, this paper presents a new topology boost converter to boost the voltage level with improved efficiency by controlling with Kalman MPPT technique. Also, a RNN-based current control technique using hebbian-LMS algorithm is proposed. The results shown above, assures that the chosen high gain converter is able to boost the gain of voltages and also, the proposed RNN based current control technique with hebbian-LMS algorithm presents the better performance over conventional PIcurrent controller in terms of stability and power quality.

Renewable PV systems are the finest energy source available in the electrical market today. Poor power quality with dynamic load changes and low PV terminal voltages are two difficulties that make it challenging to integrate PV systems into the public power grid. A unique architecture boost converter that employs Kalman MPPT control raises the voltage level more successfully. An RNN-based Hebbian LMS flow control system is also advised.

According to the data shown above, the high gain option increases converter voltage. Additionally, the Hebbian LMS algorithm-based RNN-based current control system beats the conventional PI current controller in terms of stability and power quality. Addition Of Fuel Cells Into The Proposed Configuration Boosts The Performance Of The System As It Injects 50kw Power To The Grid Irrespective Of The Solar System To Over Come The Disadvantages Of Solar Like Radiation And Temperature Effects

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