

Power enhancement in a grid connected solar PV

System by using PLL-neural based converter

Avinash kumar
M. Tech. Scholar
Dept. of Electrical & Electronics
Engineering
Corporate Institute of Science &
Technology, Bhopal, India
avinashthakur0009@gmail.com

Vivek Kumar Kostha
Assistant professor
Dept. of Electrical & Electronics
Engineering
Corporate Institute of Science &
Technology, Bhopal, India
SanjeevJarariya@gmail.com

Satyam Kumar Prasun
M. Tech. Scholar
Dept. of Electrical & Electronics
Engineering
Corporate Institute of Science &
Technology, Bhopal, India
prasun.satyam@gmail.com

Abstract-This work deals with neural network control algorithm-based grid connected to solar photo voltaic (PV) system consisting of DC-AC converter. The reference solar-grid current for three-leg VSC are estimated using neural network control algorithm. The neural network control algorithm based solar PV system is modeled in MATLAB R2018a along with SIMULINK.. This study presents an artificial neural network-based controller for regulating the level of active and reactive power output. First, the three phase currents from the VSI are measured and compared with the three reference currents. The neural network is trained to have minimum output error. It was concluded that the power output from the system was found to be 190 KVA in case of system having no intelligent controller and 700 KVA in case of system with AAN based control. The voltage of output is maintained to be 20 kV in the grid system for analysis purpose. Thus the proposed control is expected to be implemented in the renewable energy resources for better output.

Keywords: neural network control algorithm, solar PV system, DC-AC converter, active power,

I. Introduction

Solar photovoltaic (PV) energy conversion system has shown increase at a moderate annual rate of 60% in the last five years. This is possible because of alternate clean energy sources, reduction of cost, and efficiency increase of PV modules and subsidy scheme of political regulations. PV installation is classified according to their functional and operating requirements named standalone and grid connected. With standalone system, remote area is supplied by DC or AC power with converters and

energy storage devices. On the other hand, in grid connected, generated power supply to the utility services without any energy storage equipment's that have made added advantage of 99% benefit than standalone system.

In grid connected inverter, the power generated by PV plant is directly given to the transmission line and it is distributed. Henceforth, the use of batteries and other energy storage devices is not required that makes the arrangement less space, reduced investment cost and maintenance than standalone system. The evolution of solid state inverter technology and its control strategy have established PV systems into the grid. Due to variation of input supply at the inverter side, the PV inverter topology and its control design is made robust with the promising control structure. The dc-link voltage is fixed to supply constant voltage to the inverter.

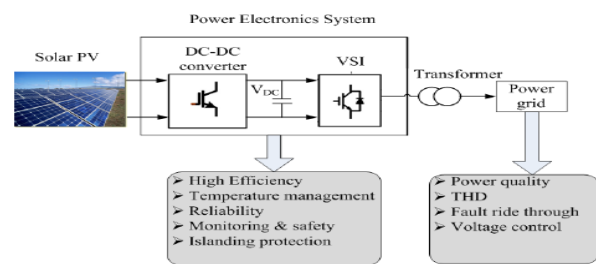


Figure. 1 Generic structure of grid connected PV system

II. LITERATURE REVIEW

Roopa Viswadev et al. [1] This paper presents a simple yet accurate control strategy for three-level four-wire grid-tie inverters for real and reactive power injection which operates satisfactorily under distorted grid conditions. Researchers have been focusing on improved topologies and control strategies in order to enhance the

performance of solar grid-tied inverters, especially during grid faults.

T. Kerekes et al. [2] the aim of the paper is to realize a survey of recent Grid Codes (GC) and regulations for grid connected PV systems. The focus is on grid interface requirements, power quality concerns and Anti-Islanding (AI) issues regarding PV systems connected to low voltage (LV) and medium voltage (MV) levels of the network. The growing share of this decentralized generation plants started to affect the grid stability and Distribution System Operators (DSOs) had to keep the safety and reliability of the network under strict rules and regulations.

S. Kouro et al. [3] This paper presents an overview of the existing PV energy conversion systems, addressing the system configuration of different PV plants, and the PV converter topologies that have found practical applications for grid-connected systems. This growth has also triggered the evolution of classic PV power converters from conventional single phase grid-tied inverters to more complex topologies in order to increase efficiency, power extraction from the sun, reliability, while not impacting the cost.

L. B. G. Campanhol et al. [4] this paper presents a three-phase grid-connected photovoltaic (PV) system, which is implemented using the neutral-point-clamped (NPC) inverter. A current feed-forward control loop (FFCL) is proposed to improve the PV system dynamic behavior, due to the PV array being constantly subjected to sudden solar irradiance change, which causes voltage oscillations in the dc bus and, hence, interferes in proper PV system operation. Extensive experimental results based on a digital signal processor are presented in order to evaluate the effectiveness, as well as the static and dynamic performance of the PV system.

III.OBJECTIVE

- Design a Solar PV Energy System using MALAB/SIMULINK environment which can be integrated with grid using a boost converter and inverter.
- Study the Artificial intelligence based neural network search that is designed to supply pulses to the inverter. It is intended to enhance the active power output from the system after conversion from DC to AC inverter
- Designing of the neural network is made such that it will the minimize the error signal and then optimize the converter output. The grid voltage and current are taken as input parameters for generating pulses and then integrating the control with the neural network for better results

- Neural network need to be designed effectively such that it will enhance the system efficiency of solar PV system. Further the work is intended to integrate the system with the grid also in order to enhance the system efficiency

IV.METHODOLOGY

1) Implementation Details

This chapter comprises with an analytical and numerical description of proposed algorithm for sentiment analysis of a power buffer which is simulated to obtain the performance of the proposed algorithm.

In order to evaluate the performance of proposed algorithm scheme, the proposed algorithm is simulated in following configuration:

Pentium Core I5-2430M CPU @ 2.40 GHz
4GB RAM
64-bit Operating System
Matlab Platform

2) Simulation Environment

MATLAB stands for MATrix LABoratory, which is a programming package exclusively designed for speedy and effortless logical calculations and Input/output. It has factually hundreds of inbuilt functions for a large form of computations and plenty of toolboxes designed for specific analysis disciplines, as well as statistics, optimization, solution of partial differential equations, information analysis.

In this research work MATLAB platform is used to show the implementation or simulation of implemented algorithm performance. Measurement toolboxes are used and some inbuilt functions for generating graphs are used. Simulation results and comparison of the performance of implemented model with some existing ones are calculated by MATLAB functions.

3) Solar PV Modeling

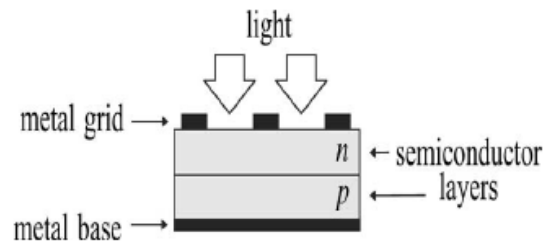


Figure 2 Structure of a Solar cell

A PV cell generates a voltage of around 0.5 to 0.8 volts depending on the semiconductor and the built-up technology. To increase the voltage cells are connected in series (36 or 72 cell) to form a module. With series and parallel combination of modules PV panel are formed.

When modules are connected in series, their voltages are added but current remains same, when connected in parallel, their currents are added while the voltage remains the same.[8] Equivalent circuit model of the solar solar cell is shown in figure 3.

A cell series resistance (R_s) is connected in series with parallel combination of cell photocurrent (I_{ph}), exponential diode (D), and shunt resistance (R_{sh}), I_{pv} and V_{pv} are the cells current and voltage respectively. It can be expressed as

$$I_{pv} = I_{ph} - I_s \left(e^{q(V_{pv} + I_{pv}R_s)/nKT} - 1 \right) - (V_{pv} + I_{pv}R_s) / R_{sh}$$

Where:

- I_{ph} - Solar-induced current
- I_s - Diode saturation current
- q - Electron charge ($1.6e^{-19}C$)
- K - Boltzmann constant ($1.38e^{-23}J/K$)
- n - Ideality factor (1~2)
- T - Temperature 0K

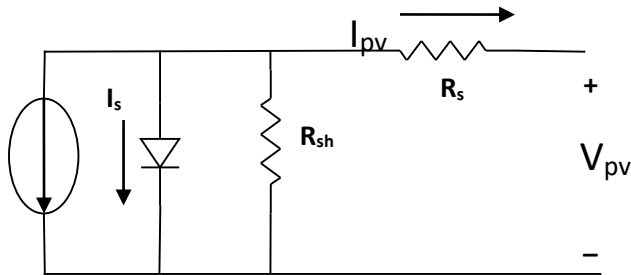


Figure 3 Equivalent circuit of solar pv cell

The solar induced current of the solar PV cell depends on the solar irradiation level and the working temperature can be expressed as:

$$I_{ph} = I_{sc} - k_i(T_c - T_r) * \frac{I_r}{1000}$$

Where:

- I_{sc} Short-circuit current of cell at STC
- k_i Cell short-circuit current/temperature coefficient (A/K)
- I_r Irradiance in w/m
- T_c , T_r Cell working and reference temperature at STC

A PV cell has an exponential relationship between current and voltage and the maximum power point (MPP) occur at the knee of the curve as shown in the Fig 4.

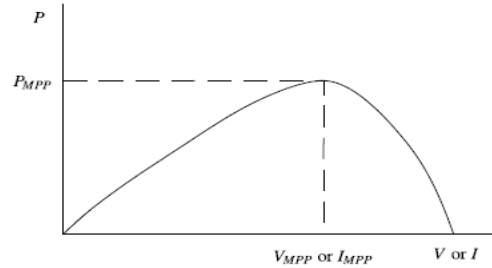


Figure 4 Characteristic PV array power curve

The P&O algorithm will track the maximum power to supply the DCMGs system. The assumptions for model derivation are that the ideal current source can be presented as the PVs behavior. In addition, all power converters are operated under the continuous conduction mode (CCM) and the harmonics are also ignored.

4) PWM technique

Since the DC bus voltage is always constant, the inverter has to be controlled to vary the magnitude and frequency of AC output voltage. This is normally accomplished by PWM technique.

The fundamental methods of pulse-width modulation (PWM) are divided into the traditional voltage-source and current-regulated methods. Voltage-source methods more easily lend themselves to digital signal processor (DSP) or programmable logic device (PLD) implementation. In discrete current-regulated methods the harmonic performance is not as good as that of voltage-source methods.

The Pulse Generator block generates square wave pulses at regular intervals. The block's waveform parameters, **Amplitude**, **Pulse Width**, **Period**, and **Phase Delay**, determine the shape of the output waveform. The following diagram shows how each parameter affects the waveform.

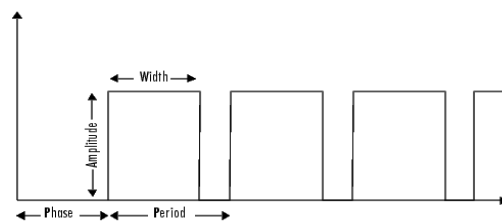


Figure 5 Regular pulse generation technique

The Pulse Generator can emit scalar, vector, or matrix signals of any real data type. To cause the block to emit a scalar signal, use scalars to specify the waveform parameters.

To cause the block to emit a vector or matrix signal, use vectors or matrices, respectively, to specify the waveform parameters. Each element of the waveform parameters

affects the corresponding element of the output signal. For example, the first element of a vector amplitude parameter determines the amplitude of the first element of a vector output pulse. All the waveform parameters must have the same dimensions after scalar expansion. The data type of the output is the same as the data type of the Amplitude parameter.

5) ANN

ANNs are information processing systems that simulate the behavior of the human. ANNs obtain the inherent information from the considered features and learn from the input data, even when our model has noise. ANN structure is composed of essential information processing units, which are neurons.

They are defined into several layers and interconnected with each other by defining weights. Synaptic weights show the interaction between every pair of neurons. These structures distribute information through the neurons. The mappings of inputs and estimated output responses are calculated through combinations of different transfer functions. We can use the self-adaptive information pattern recognition methodology to analyze the training algorithms of the artificial neural networks. The most commonly used computation algorithm is the error back propagation algorithm.

Neural networks can be divided into single-layer perception and multilayer perception (MLP) networks. The multilayer perception network includes multiple layers of simple, two state, sigmoid transfer functions having processing neurons that interact by applying weighted connections. A typical feed-forward multilayer perception neural network consists of the input layer, the output layer, and the hidden layer. The multilayer perception (MLP) with the back propagation learning algorithm is used in this study because numerous previous researchers used this type of ANN, and it is also a general function approximate.

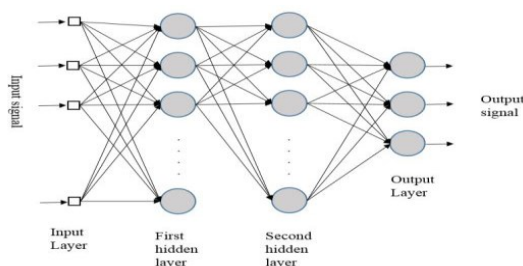


Figure 6 Architectural Graph of an MLP Network with Two Hidden Layers.

The development of ANN models was based on studying the relationship of input variables and output variables. Basically, the neural architecture consisted of three or more layers, i.e. input layer, output layer and hidden layer

as shown in Fig. 6. The function of this network was described as follows:

$$Y_j = f\left(\sum_i w_{ij} X_{ij}\right)$$

where Y_j is the output of node j , $f(\cdot)$ is the transfer function. w_{ij} the connection weight between node j and node i in the lower layer and X_{ij} is the input signal from the node i in the lower layer to node j .

6) Artificial Neural Network For Inverter

An inverter is an electronic circuit that converts DC to AC power by switching the DC input voltage (or current) in a pre-determined sequence to generate AC voltage (or current) output. The topology used here consists of three phase bridge inverter. The conversion from DC to AC using the power electronic device introduces harmonics in the output voltage.

The Optimal Switching Pattern Pulse Width Modulation (PWM) strategies constitute the best choice for high power, three-phase voltage controlled inverter with low allowable level of switching frequency.

The proposed project is presented in the following phases namely,

1. Taking the output voltage and current as an input
2. Training of neural network
3. Gate pulse generation of inverter circuit

Neural network (NN) has been employed in many applications in recent years. An NN is an interconnection of a number of artificial neurons that simulates a biological brain system. NN have been successfully introduced into power electronics circuits to generate the optimal switching angles of a PWM inverter for a given modulation index.

The PWM generator generates the switching signals to the full-bridge inverter. For linear load, the output voltage is pure Sinusoidal. The schematic block diagram representation as shown in figure1.

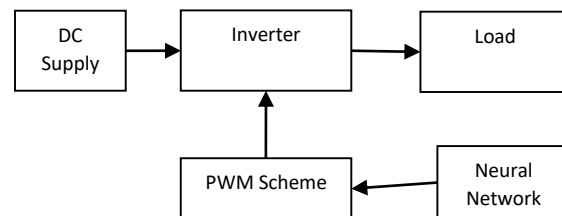


Figure 7 Basic Block diagrams for the inverter control

Neural network deals with Mathematical information about processing of a system with input and output. A neural network used for generation of optimal switching angles has a single input for the reference value of the modulation index and N outputs that provide the values of

the switching angles. The neurons are trained using the Neural Network toolbox of MATLAB.

The proposed modulation scheme is based on Artificial Neural Network system. The modulation algorithm can be looked upon as a nonlinear input/output mapping. The reference voltage vector V^* magnitude and α^* angle have generated using pulse width modulation scheme for the dual three-phase voltage source inverter in and the corresponding pulse width pattern is at the output. Fig. 7 is showing the neural network plan for the simulation.

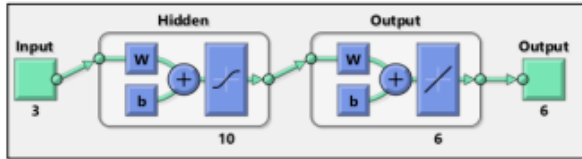


Figure. 8 Neural network plan with neurons in hidden layer

V. RESULTS

The model has been developed in MALAB/SIMULINK environment. It is a matrix / matrix matrix language with control flow instructions, functions, data structures, inputs / outputs and object-oriented programming functions. It has the following main features:

- High level language for scientific and technical computer science
- Desktop environment for exploring, designing and solving iterative problems
- Graphs to display data and tools to create customized graphs
- Applications for curve adaptation, data classification, signal analysis, control optimization and many other tasks
- Complementary toolboxes for various technical and scientific applications
- Tools to create custom applications for the user interface
- Distribution options at no cost for sharing MATLAB programs with end users

In a grid connected PV system, also known as a “grid-tied”, or “on-grid” solar system, the PV solar panels or array are electrically connected or “tied” to the local mains electricity grid which feeds electrical energy back into the grid. Grid connected PV systems always have a connection to the public electricity grid via a suitable inverter because a photovoltaic panel or array (multiple PV panels) only deliver DC power.

Here in this work we have achieved a Photo voltaic system interfaced with the grid having neural based

inverter control. The chapter discusses the output from the system in two broad cases.

CASE 1 : PV system having inverter without neural based control

CASE 2 : PV system having inverter with neural based control

The chapter has described the PV module whose output has been compared in order to drive the relative comparison between the above two scenarios. The system has been modelled to be interfaced with the grid system which modelled as a three phase voltage source 120KV which will be made to maintain the grid voltage of approximately 20 KV after passing it through a three phase transformer.

After making two inverter controls for the system output active power and reactive power are to be studied and further are compared with those modelled with neural network.

In order to ensure efficient operation of the solar array the MPP of the array has to be tracked. MPPT, in addition to rise the power delivered from the PV module to the load, is considered as a PV system booster. The MPPT technique that generates the control signal feeds the boost converter.

The figure 5.1 shows the PV system whose output DC voltage is first passed through a DC-DC boost converter having control of MPPT based basic P and O algorithm. The DC output is then fed to the inverter for further conversion from DC to AC voltage.

For modelling the solar PV system the input radiation is kept to be 1000 weber per square meter and the temperature of approximately 25°C. The input temperature and irradiation on the solar modules produces DC output voltage which is then fed to the boost converter. This PV system has been modelled with modules of power rating 300 Watts.

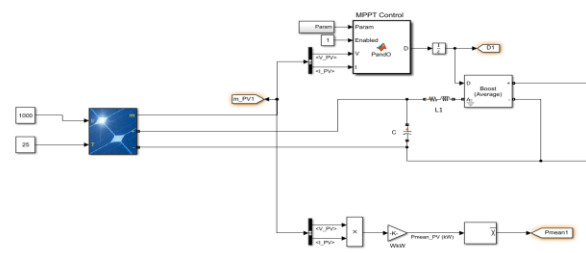


Figure 9 : MATLAB/SIMULINK model of solar PV system

The DC output from the above model has been depicted in Figure 5.2. The DC output is found to be approximately 400 Volts.

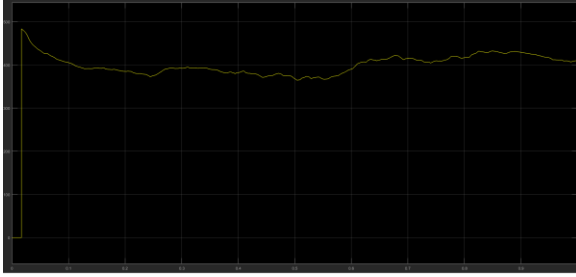


Figure 10: MATLAB/SIMULINK model of solar PV system

CASE 1: PV SYSTEM HAVING INVERTER WITHOUT NEURAL BASED CONTROL

Figure 5.3 depicts the solar PV system integrated with the grid system. The inverter control is not provided with the artificial intelligence controller. Simple voltage and current regulator based inverter control has been used. The grid voltage and current is taken as input in the inverter control and is used to generate pulses on the same basis.

Four inverters of having snubber resistance of 1×10^8 ohms is being used. The DC voltage supplied to the inverter is 400 V and the output range is 160–300V. Power switching device used is of IGBT type and the number of arms formulating the bridge is three.

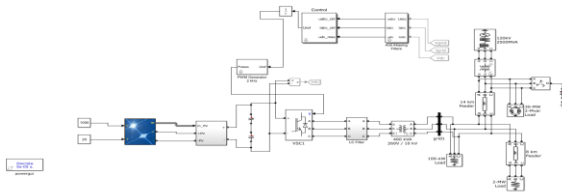


Figure 11 PV System without Neural based control

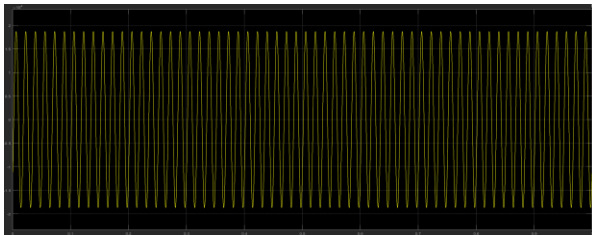


Figure 12 Per phase output voltage from the system without Neural based control

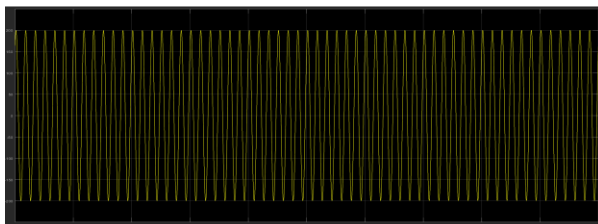


Figure 13 Per phase output current from the system without Neural based control



Figure 14 RMS value of Active Power Output from the system without Neural based control



Figure 15 RMS value of Reactive Power Output from the system without Neural based control

The above waveform shows the voltage and the current output from the converter along with the RMS value of active power and reactive power that would be later said to the Transformer to be further integrated with the Grid.

It can be seen that that is power from the inverter with basic PLL control having no neural network interfacing is found to be 190 KVA which is the RMS value for the active power coming from the inverter. The voltage output is maintained to be 20 KV.

CASE 2: PV SYSTEM HAVING INVERTER WITH NEURAL BASED INVERTER CONTROL

The technique of current control has the most important role in current-regulated pulse-width modulation (PWM) inverters which are widely used in AC motor drives, reactive power compensators and active power filters. Neural network techniques have grown rapidly in recent years. Extensive research has been carried out on the application of artificial intelligence. Artificial neural network technology has the potential to provide an improved method of deriving nonlinear models. This study presents an artificial neural network-based controller for regulating the level of active and reactive power output.

First, the three phase currents from the VSI are measured and compared with the three reference currents. The neural network is trained to have minimum output error. The inputs to the neural network are three phase current errors and the outputs are the inverter switching patterns. NN2 is used to generate an appropriate control signal in order to force error to be as small as possible. Since the

neural networks have learning capability, neural network control can automatically learn the dynamic characteristics of the DC-AC converters.

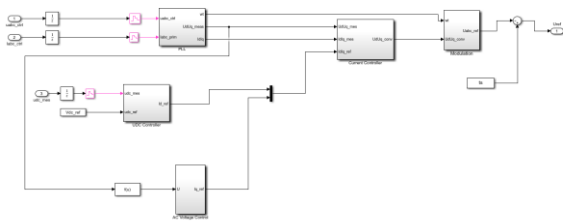


Figure 16 System with neural based control of inverter

The system in this case is modelled solar energy with using neural network based converter that is also integrated with the grid. Further the voltage current, active power and reactive power waveforms have been analysed.

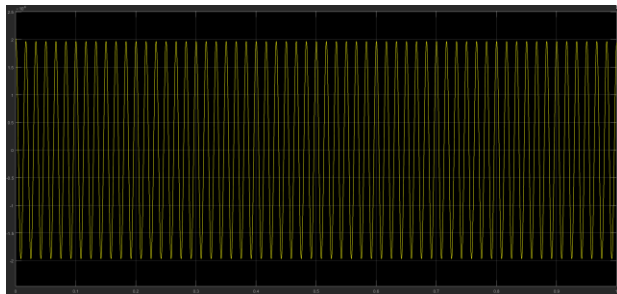


Figure 17 Per phase output voltage from the system with Neural based control

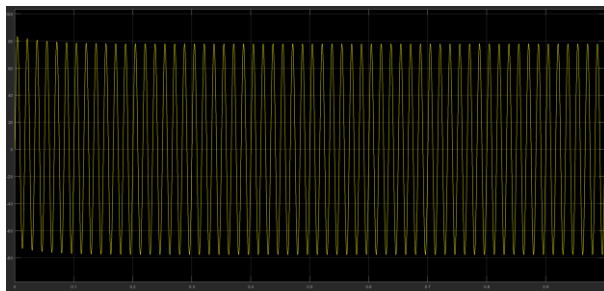


Figure 18 Per phase output current from the system with Neural based control



Figure 19 RMS value of Active Power Output from the system with Neural based control

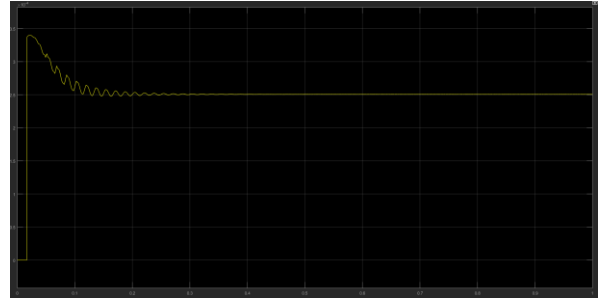


Figure 20 RMS value of Reactive Power Output from the system with Neural based control

The above waveform shows the voltage and the current output from the converter having neural network based control along with the RMS value of active power and reactive power that would be later sent to the Transformer to be further integrated with the Grid.

It can be seen that that is power from the inverter having neural network interfacing is found to be approximately 700 KVA which is the RMS value for the active power coming from the inverter. The voltage output is maintained to be constant with 20 KV for the transmission line.

Thus NN is making the active power available enhanced and after keeping the voltage output constant.

From the above results it can be concluded that the RMS value of active Power output is with the inverter having no neural network based control is found to be less as compared to the inverter having neural network based control. Thereby making the system more reliable for driving heavy loads as compared to the system with no AI based control.

VI. CONCLUSION

Artificial intelligence (AI) techniques play an important role in modeling, analysis, and prediction of the performance and control of renewable energy. The algorithms employed to model, control, or to predict performances of the energy systems are complicated involving differential equations, large computer power, and time requirements. Instead of complex rules and mathematical routines, AI techniques are able to learn the key information patterns within a multidimensional information domain.

The scope of the work includes development of inverters/controllers for grid-interactive solar distributed generation systems that will:

- incorporate energy management functions and/or power control and conversion for energy storage, or
- Include the ability to interface with energy management and energy storage systems, smart appliances, and grid, including adaptation of these systems to communicate with and/or control the inverter/controller.

The work proposes neural network control for the inverter during DC to AC conversion for obtaining the above objectives. The following main conclusions were drawn during the analysis of solar PV system in MATLAB/SIMULINK environment.

- Solar photovoltaic system with inverter having neural network which takes the grid voltage and current as input parameters to generate the controlling pulses is established with grid interfacing.
- The active power output from the solar photo voltaic system having simple inverter control was found to be approximately 190KVA.
- The active power output from the system with neural network based control of inverter was found to be approximately 700KVA. The improvement of approximately 500 KVA has been observed.
- The system has been integrated with the grid for making it more reliable. Also power being fed to the grid via transformer in case of solar system with neural network based inverter control is more as compared to the system without it.
- The model is expected that it would be able to drive the load, both linear and nonlinear more effectively and efficiently

VII. FUTURE SCOPE

Improving the quality of energy can be achieved by using a more efficient power enhancement and algorithm in a networked system. The work can be extended to improve the quality of the network fed to the network through renewable energy sources making it a hybrid system. The modulation technique is easy and simple to be implemented, use of proper facts devices can make it more robust and easy to handle inverter.

With the advent of more powerful DPS, the requirements for low computational complexity and memory consumption of the algorithms will drop and it might be even possible to implement more complicated and more efficient algorithms. Therefore, it is certainly true that the area of AI is and for a long time will remain widely opened sphere for scientific research and commercial applications

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