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Neural Network Based Inverter Control for Improving Power Quality in Grid Connected PV system

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Abstract: Grid connected PV system is always a matter of concern in terms of power quality (PQ). The effective way for improving PQ is implementation of proper inverter control and racking of solr output voltage-current. In the proposed work the inverter gain parameters are tuned using neural network. Inverter is designed with conventional PI controller and the gains are trained with the grid variable like voltage/current and the output of PI is set with respect to grid. The NN predicts the gain parameters of the PI controller as per the grid side parameter variation and the PQ of the grid side has been enhanced. The system has been designed in MATLAB simulation environment. The performances has been studied for static as well as non-linear loading and for the grid sag condition to obtain low losses and high recovery with low THD content.
Keywords: Hybrid Power Control System (HPCS), Automatic Transfer Switch (ATS), relays, contactors. 10

I. INTRODUCTION

The need of the time is to increase the use of renewable resources in order to meet the load demand and reduce the carbon emission. PV system finds application in supplying local loads or connected to the distribution system or operate as a microgrid where local generation is carried out [1, 2]. PV systems can provide clean power for small or large applications. Hence they could be installed as standalone or grid connected system. PV systems are preferred as stand-alone systems, where it is difficult to connect to the grid or where there is no energy infrastructure [3-6]. Electricity can be imported from the network when there is no sunlight. Such small installations are also easy to set up and connect to the grid [7]. The rules about grid connection vary from country to country, but almost in all countries it is compulsory to contact the local network system operator [8, 9].

A lot of ongoing research has been reported in literature for auxiliary services on power quality improvement through proper control of converters. These converters can perform dual work of interfacing solar system with the grid and also conditions the power at point of common coupling.

The technological evolution has made the operation of grid connected PV system (GCPVS) with high efficiency, low losses, less maintenance and highly reliable. GCPVS if not controlled properly, may distorts the grid profile and increase the power quality (PQ) issues like voltage and current perturbation, swell and sag in voltages, harmonics, etc. If these PQ issues are not rectified at load end, it may distort the grid profile hence other system too connected to the grid. There are numerous controllers available in literature which can be employed to mitigate the numerous PQ issues. Hence for successful GCPVS operation inverter control plays a very vital role. To reduce the investment, operation and maintenance cost, man-hour, as-well-as the bulk, and enhance the cost-effective feature of the GISPV grid-connected inverters plays important role [10–16]. The GISPV inverter control can connect RESs and storage devices to utility grid, and simultaneously enhance the power quality at their points of common coupling (PCCs). Hence they are capable of saving capital investment and system space. The internal dynamics of PV system also needs to be studied for stability aspects hence a MPPT controller is employed to stabilize the PV parameters like voltage-current output.

In this paper a three-phase GCPVS incorporating Modified Neural Network Based Proportional Integral (MNNPI) inverter control algorithm is designed [10-14]. The converter designed can perform dual work of interfacing solar system with the grid and also conditions the power at point of common coupling. In the proposed work the inverter gain parameters are tuned using neural network. Inverter is designed with conventional PI controller and the gains are trained with the grid variable like voltage/current and the output of PI is set with respect to grid. The difficulty of using a PI controller is the necessity of tuning the gain with changes in atmospheric conditions or loaded conditions. The NN predicts the gain parameters of the PI controller as per the grid side parameter variation and the PQ of the grid side has been enhanced. The system has been designed in MATLAB simulation environment. The performances has been studied for static as well as non-linear loading and for the grid sag condition to obtain low losses and high recovery with low THD content.

This paper is organized as; in section II system configuration with controller design is presented. Section III presents the proposed work. Simulation results are presented in section IV. At the end conclusion is given in section V.

II. SYSTEM CONFIGUATION AND DESIGN

The state-of-art of the GCPVS with proposed MNNPI controller is shown in Fig.1. For a three-phase PV system grid connected via inverter, LC filter and point of common coupling (PCC). The inverter converts the DC supply into AC and fed to the LC filter. The main aim of the grid connected PV topology is given a constant power flow parameters for both the normal and abnormal conditions. During the grid faulty condition develops the PQ issues in the grid connected PV systems.

By employing the suggested hybrid control technique the reported problems can be corrected. The suggested hybrid control technique contains two cascaded loops like inner current loop which has the liability for power quality issues and current protection and an outer voltage control loop [30]. The proposed control technique is used to generate the control pulses of the inverter by utilizing the grid parameters.

The LC filter is employed as the output filter in order to limit the higher order harmonics coming from the inverter switching behavior as it can be seen in Fig. 1. Hence, ignoring all the filter losses, the system at the ac side can be explained in the subsequent equation (1) [15].

$$\frac{di_g(t)}{dt} = \frac{V_{inv}(t)}{L} - C_f \frac{d^2V_g(t)}{t^2} - \frac{V_g(t)}{L} \qquad (1)$$

The stochastic behavior of the PV system may leads to unreliable grid connected operation. A proper DC-voltage regulator may some extent help to stabilize the solar performance. In this work this has been accomplished by Incremental conductance MPPT algorithm. Also for efficient grid integrated operation; the designed inverter must meet the grid code requirements. Hence in the proposed work, to integrate the PV system with the grid a DC/AC inverter is simulated using NN based PI controller. The designed inverter is also efficient under faulty condition.

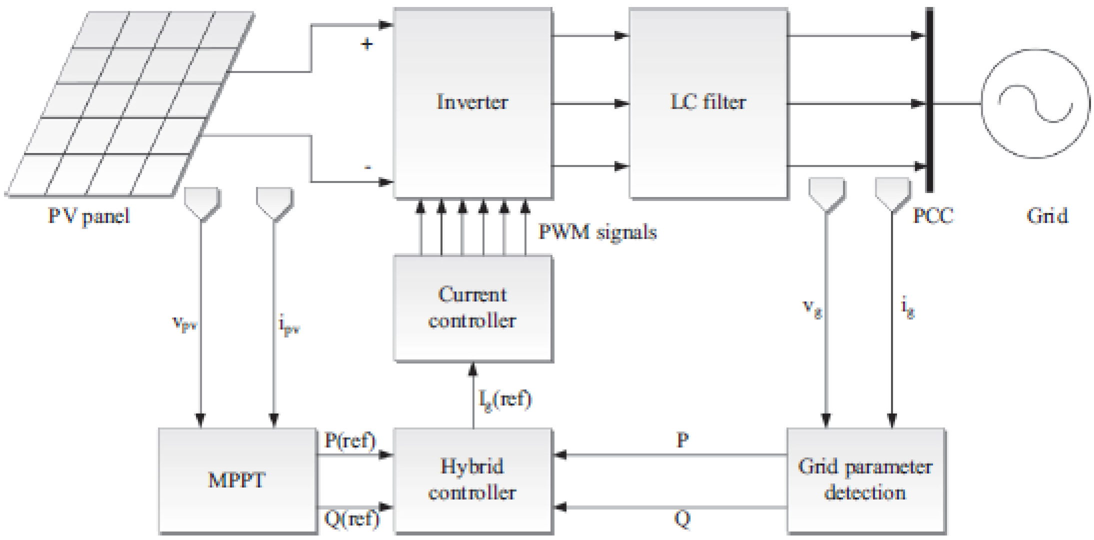


Figure -1 Block diagram of the proposed system.

A) Proposed HNNPI Controller Design

The HNNPI is trained with input parameters such as grid power variations and the target gain parameters of the PI controller. During the testing time, the HNN predicts the gain parameters of the PI controller as per the grid side parameter variation and the PQ of the grid side has been enhanced. For three phase system to reduce complexity an abc-dq transform is used as shown in figure-2. A conventional three leg full bridge universal inverter is used. The inverter is synchronized with the grid using phase lock loop referenced using grid current. The Kp and Ki gain for PI is 0.01 and 500.

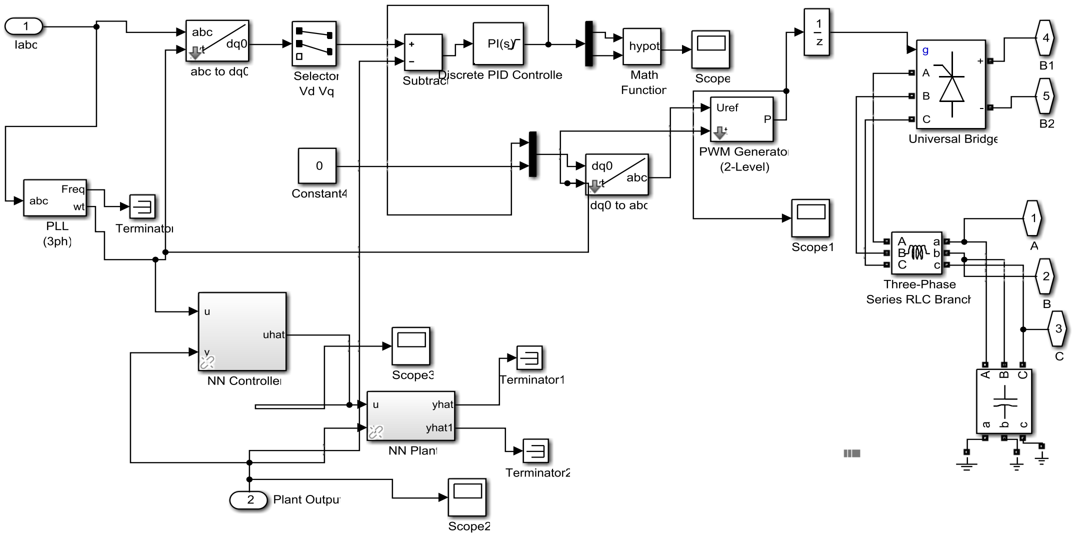


Figure 2 Proposed HNNPI controller

B) Filter Design

A low-pass filter (LPF) is a filter that passes signals with a frequency lower than a selected cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency. The exact frequency response of the filter depends on the filter design. In utility system filters has tremendous utilization since the harmonics present in the voltage and current can be eliminated with the help of filters. The basic configuration of LPF is presented in figure 3.

$$C = \frac{1}{(2\pi f)^2 L}$$

$$L = \frac{0.03V_{in}}{2\pi f I_{Lmax}}$$

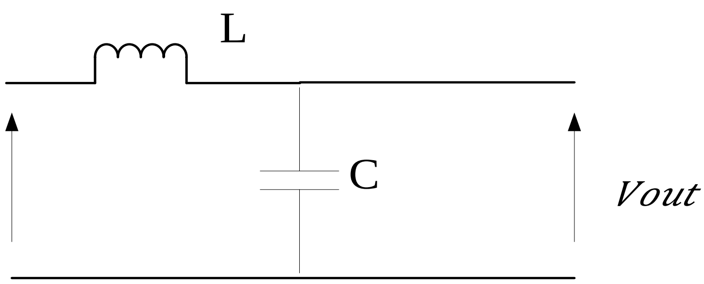


Figure 3 schematic of analog LPF

III. PROPOSED WORK

The system has been modeled using MATLAB SIMULINK tool box. The simulation model is given in figure-3.

To eliminate the PQ issues in the distribution system connected with PV via three phase inverter. The main aim of the grid connected PV topology is given a constant power flow parameters for both the normal and abnormal conditions and also to reduce the harmonic in the load and source voltage/current caused due to non-linear loading. During the grid faulty/unbalanced condition generates the PQ issues in the grid connected PV systems. By employing the HNNPI technique the reported PQ problems can be over-come. The proposed control technique is used to generate the control pulses of the inverter by utilizing the grid parameters. The parameter design selection is presented in table -1. A 150 KW PV system with 600 V PV Dc output. The proposed system is analysed under three operating conditions;

1. Under static condition with constant irradiance.
2. Under the condition of voltage sag.
3. Under the condition of non-linear loading

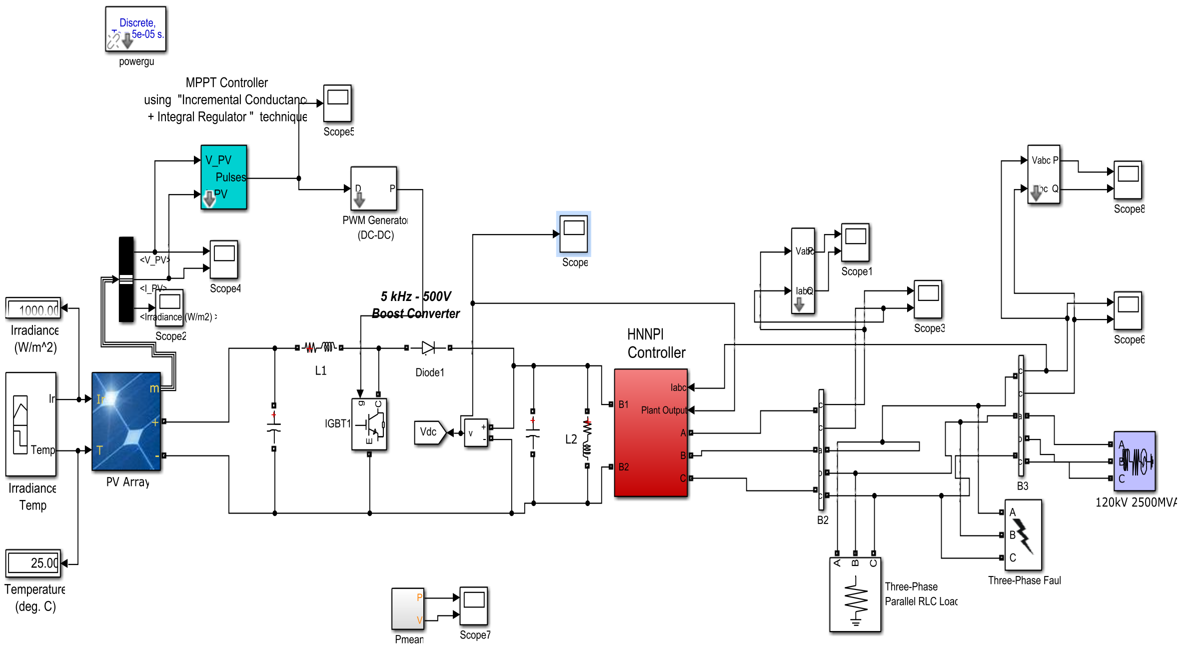


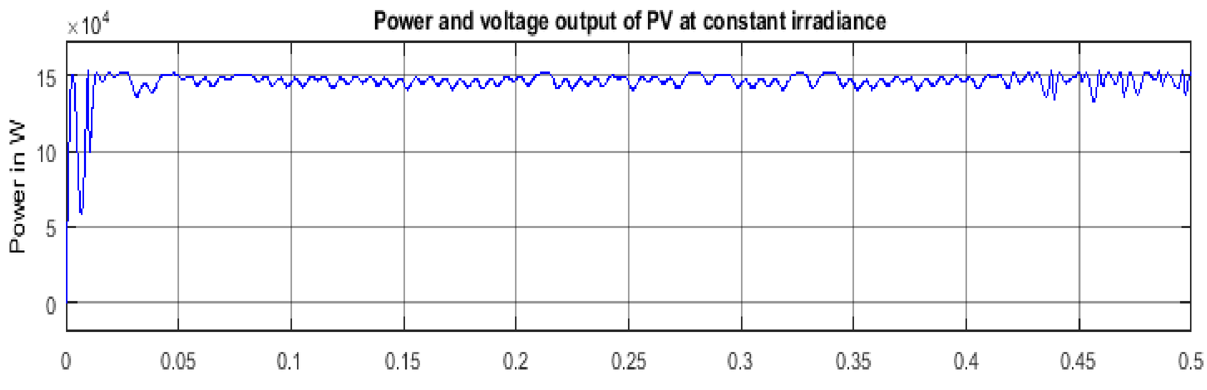
Figure 4 Matlab model of proposed MNNPI based GCPVS

Table-1Design Parameters

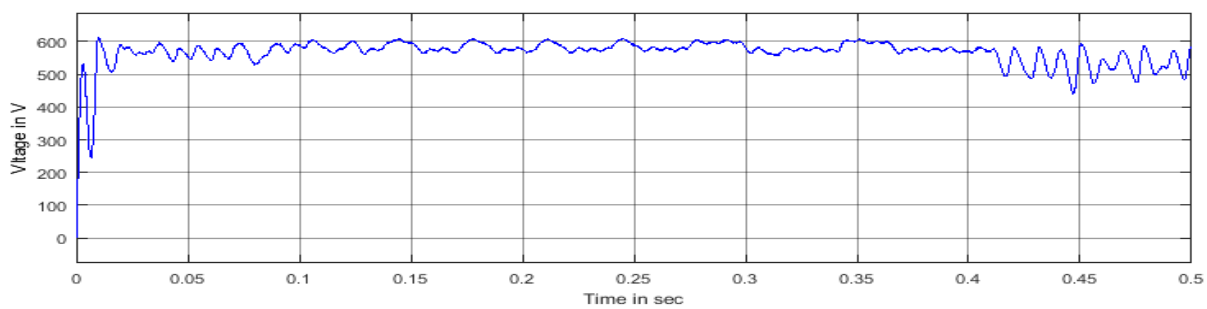
Parameter	Values
PV rating	150KW
C_{dc}	1000µF
DC converter inductance	3 mH
dc-bus voltage Vdc	1200V
Inverter parameter	
Effective nominal voltage of the utility V_S	120kV
Nominal utility grid frequency fS	50Hz
Switching frequency of the converters fch	20khz
inductance of filter	10 mH
Series resistance converter	0.01 ohms
Capacitances of the parallel filters	1500µF
Resistances of the converter filter	0.01 ohms
Gain PI; Ki, Kp	500, 0.04

IV. SIMULATION RESULT

The output power and voltage of the simulated PV panel is presented in figure 5. The performance of the GCPVS with the proposed MNNPI controller for static operating condition of grid and loading is presented in figure 6. This figure presents the output voltage and current at PCC. Figure 7 and 8 presents the voltage and current profile at PCC during non-linear loading load side and grid side respectively. Figure 9 presents the voltage and current profile at PCC during grid voltage dip. It can be seen that under this condition both voltage and current under goes dip. Now the proposed controller is connected and it generates the trained signal. Figure 10 presents the input signal to NN while figure 11 presents the trained output signal to mitigate the voltage dip at PCC. The figure 12 presents the output voltage and current or the condition of voltage dip with the proposed controller.



(a)



(b)

Figure 5 (a) Output power and (b) voltage of PV panel

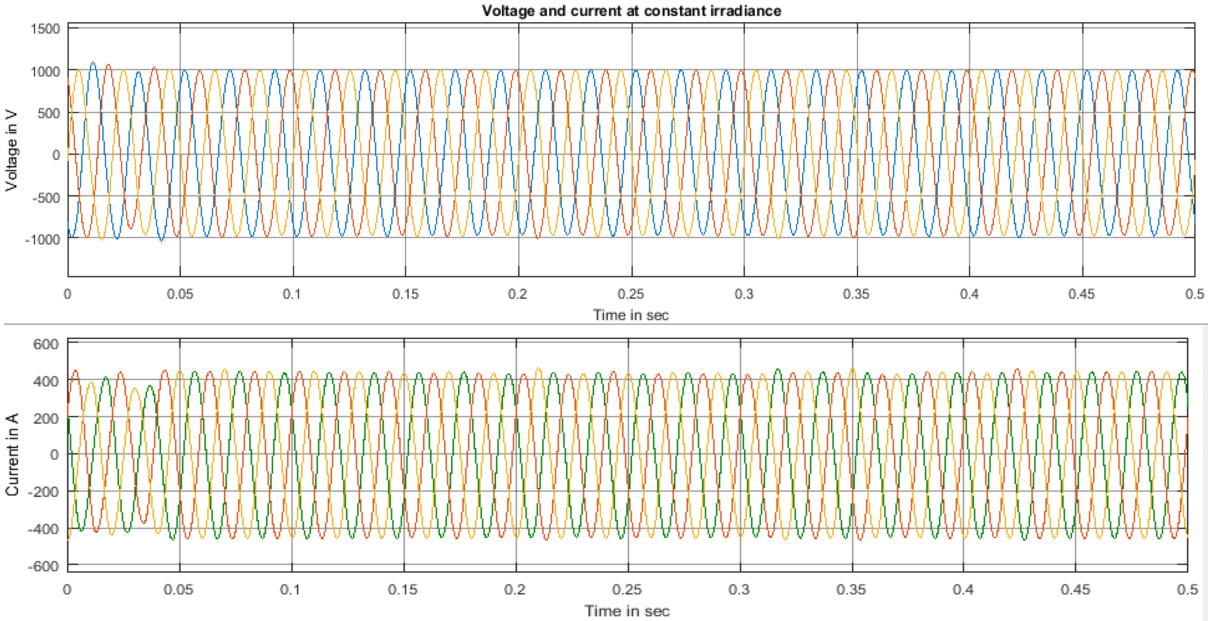
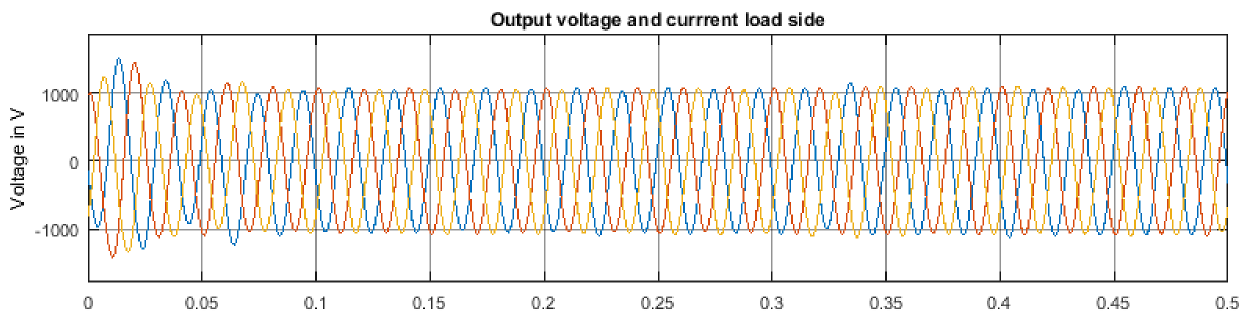


Figure 6 Output of proposed topology under constant irradiance



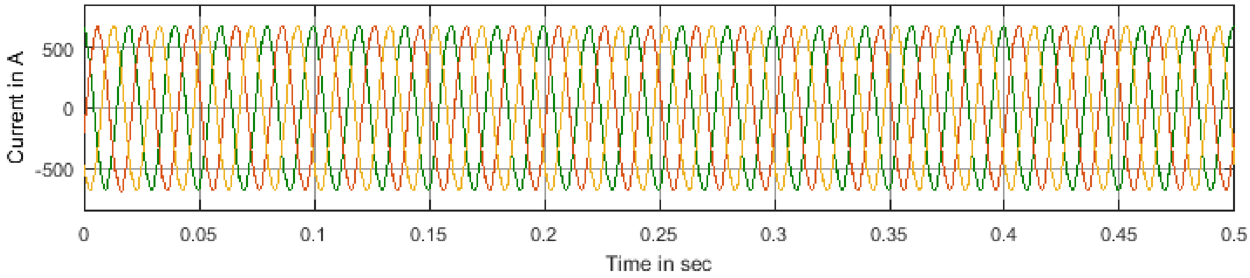


Figure 7 Output of proposed topology under the condition of non-linear loading load side.

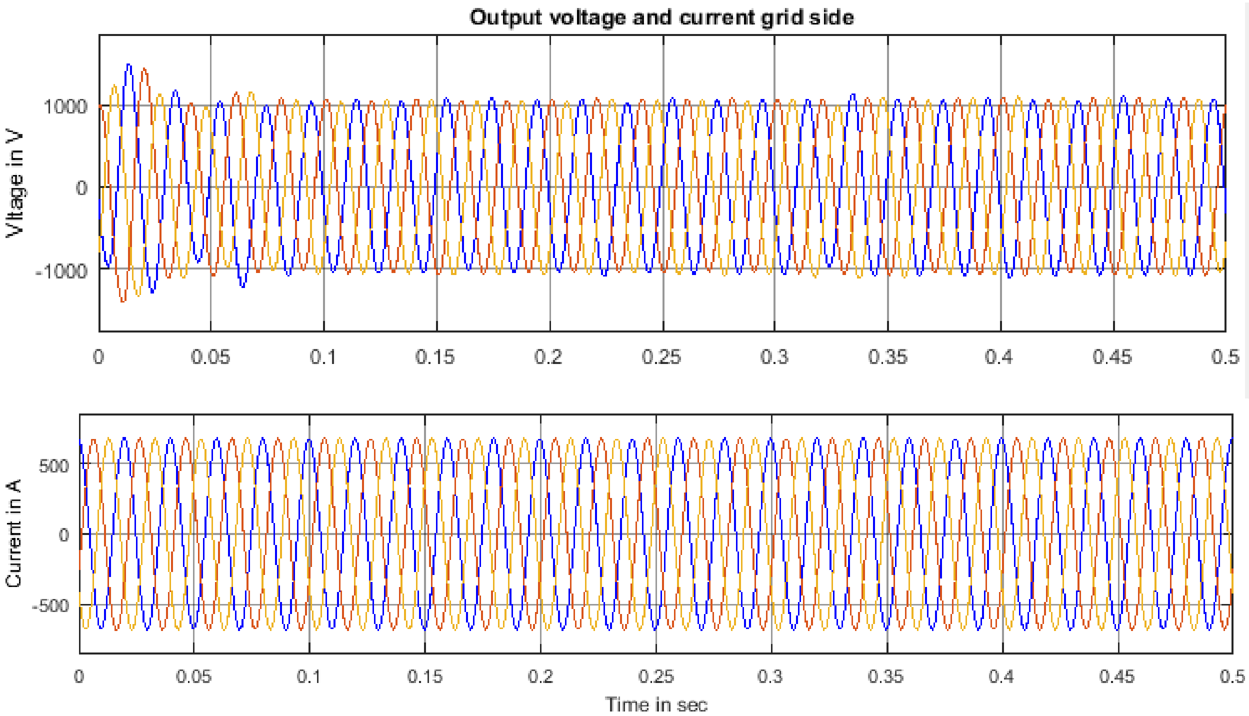


Figure 8 Output of proposed topology under the condition of non-linear loading grid side.

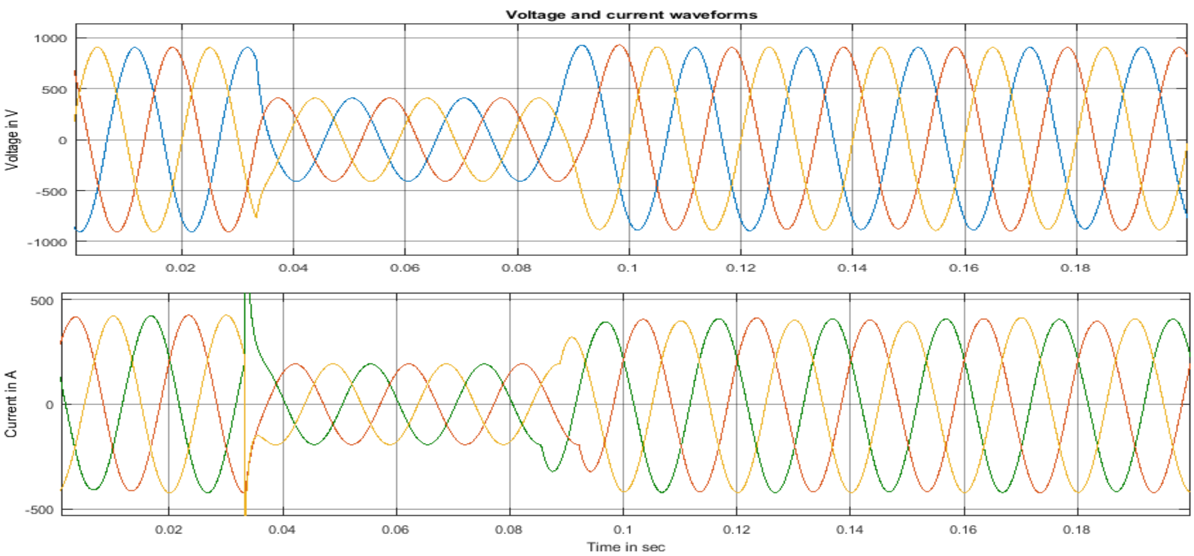


Figure 9 Output proposed topology for voltage sag condition without controller

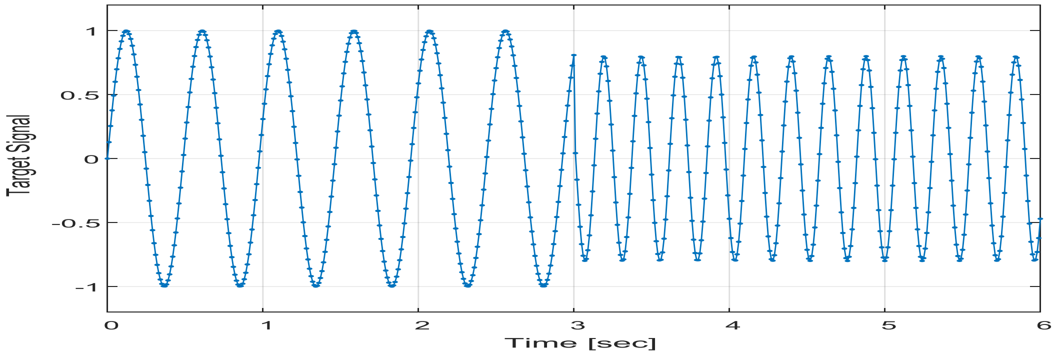


Figure 10 Output signal of NN during voltage dip grid side

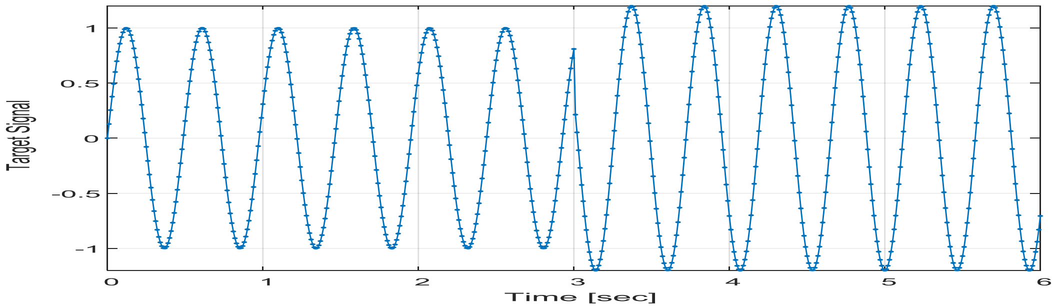


Figure 11 Recovery signal to boost the voltage during dip

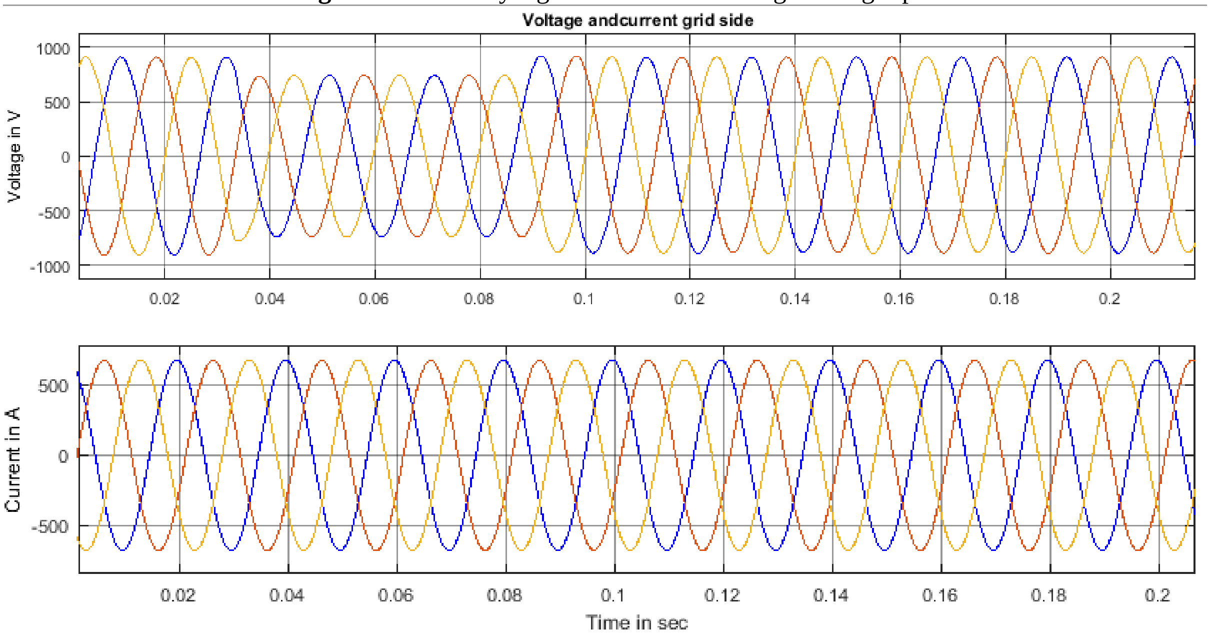


Figure12 Output proposed topology with the proposed MNNPI controller during voltage dip

Table-2 Comparison of harmonic

Operating mode	Static condition	Non-linear loading	Voltage sag
THD of grid voltage	1.2%	2.65	1.65
THD of grid current	0.1%	0.13	0.2
THD for load current	1.4%	2.08	1.85

V. CONCLUSION

A three-phase grid-connected solar photovoltaic (GCPVS) system incorporating Modified Neural Network Based Proportional Integral (MNNPI) inverter control algorithm is designed. The system has been analysed for static operation under constant irradiance and linear as well as non-linear loading. Also this paper presents the voltage and current at PCC and grid side for the condition of voltage sag. The MNNPI decides the optimal gain parameters of the PI controller based on the grid side parameters variations. By using the attained gain parameters, the PI controller has been operated and the PQ of the grid side has been enhanced. The NN is so trained so as to obtain the boosted voltage signal to mitigate the condition of voltage sag caused by the fault. The performance evaluation of the system under various operating conditions shows that the proposed controller works effectively maintaining grid profile also capable of mitigating voltage sag to a great extent. The proposed MNNPI results in low harmonics under such conditions at PCC.

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