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Design and Implementation of Closed-Loop Controlled Boost Converter for Grid-Connected Solar Rooftop System with Net Metering using Fuzzy Logic

VENKATASUBRAMANIAN S[1], AISHWARYA S[2], NETHRA SRI A[3], SHAHITHA BEGAM S[4]

[1]*Associate Professor, Dept. of Electrical and Electronics Engineering, Sri Sairam Engineering College, TamilNadu, India*
[2,3,4]*Student, Sri Sairam Engineering College, TamilNadu, India*

Abstract - Presently, Grid-connected renewable energy systems are the most sought after alternate energy sources with respect to the geographical and meteorological conditions in India, the efficiency of grid-connected solar photovoltaic systems continues to be a predicament due to the unstabilized solar output and poor power quality. The proposed project provides an energy-efficient and feasible solution to improve the power quality of the grid-connected rooftop solar photovoltaic system with net metering using fuzzy logic. This project introduces an alternative solution using a boost converter using fuzzy logic, thereby reducing the error to 2-5%. Grid-interactive inverters are used to decrease the power quality problems by minimizing voltage and current harmonics using fuzzy logic. And Net Metering is employed to automatically export the unutilized power from the solar panel to the utility grid during non-peak hours and the consumers can avail tariff compensation for the same.

***Key Words*: Renewable Energy, Solar PV system, Fuzzy Logic, Boost converters, Net metering, Grid-connected, household consumption.**

1. INTRODUCTION

With the earth getting warmer progressively, the impacts are becoming evident with every passing minute. Global warming and climate change are no longer threats of the future and people of our planet are more conscious than ever before. Alternative energy sources or clean energy sources that are renewable in nature are becoming the heart of this process. This calls for a fast-paced lifestyle change where effective clean energy sources replace the non-renewable energy sources widely used across our planet. Solar energy is one of the ideal energy sources that can help bring down the global reliance on non-renewable energy sources such as fossil fuels. Installing rooftop solar photovoltaic systems in households help in this process as 1 kWp of solar panels would reduce roughly 2 Kg of CO2 per day and 18 tonnes of CO2 over its lifetime in 25 years, making solar rooftops an ideal solution for reducing greenhouse emissions. However, Indian households have taken a lethargic approach towards it despite the multiple schemes made available by the government that brings down the high initial installation charges. These solar energy sources for households are made further cost-effective by connecting them with the grid, these are known as grid-connected solar rooftops. The proposed system provides an energy-efficient and feasible method to improve the power quality of grid-connected rooftop solar photovoltaic systems using fuzzy logic and net metering.

2. EXISTING SYSTEM

The existing system employs solar photovoltaic converters with an error percentage in the range of 10-15%. This not only increases the harmonics in the voltage and current parameters but also reduces the efficiency of the system. Solar panels are installed in households in order to reduce the power consumption, however, usage of such converters fails to achieve the purpose of installation. Thereby, the present system consists of a lot of factors that introduce harmonic distortion into the electrical lines making a grid-connected rooftop system a far fetched option for the current situation and none the expensive.

3. PROPOSED SYSTEM

The proposed system reduces the error by two folds when compared to the conventional system. This is made possible with the help of fuzzy logic. Fuzzy logic increases precision thereby decreasing the error. It is applied in two regions of application namely, at the converter and the inverter. The converter is a closed-loop boost converter which helps in achieving a constant and increased output based on the irradiance. The output of the converter is measured continuously and the results are compared with the input, the error generated is used to run the fuzzy logic. The inverter, however, uses fuzzy logic to synchronize the utility grid and consumer parameters.

4. SYSTEM ARCHITECTURE

The structure of the proposed system is shown in Figure 1. The solar panel system converts solar energy to electrical energy which is then stored in a battery that has an inbuilt charge control circuit.

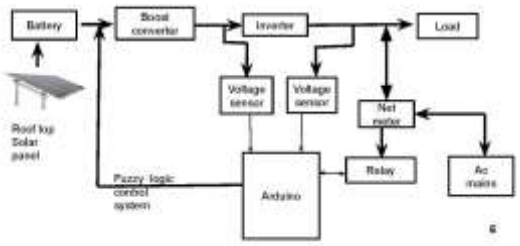

Figure 1: Block diagram of the system.

When the solar output is greater than the threshold value that is set according to the previous data, then it is sent to the boost converter. It is a closed-loop boost converter, that is, the output and input are compared at regular intervals and the error generated is applied in the fuzzy logic. The fuzzy logic brings in precision and this way the output of the converter is maintained constant. The output voltage of the converter is sensed and is sent to the Arduino where it is compared. The inverter gets its input from the boost converter, grid friendly inverters are used for this purpose in order to reduce the harmonics. The consumer utilizes the output from the inverter and the remaining unutilized power is automatically fed back to the utility grid.

4.1. WORKING

Three conditions are checked by the inverter through a microcontroller for this purpose.

CONDITION 1:

When the solar power produced is less than the consumer demand, in which case the consumer utilizes the power from the utility grid.

CONDITION 2:

When solar power produced is equal to consumer demand, then solar power is utilized.

CONDITION 3:

When solar power produced is greater than the consumer demand, in this case, the unutilized power is exported back to the grid through net metering and the consumer obtains tariff compensation.

The above three conditions are checked by the microcontroller interfaced along with the inverter thereby automating the process.

5. SIMULATIONS AND EXPERIMENTAL RESULTS

The proposed solutions for the grid-connected rooftop solar system with net-metering have been designed using MATLAB package and the voltage and current transient graphs of the PV system and the grid is obtained from the same.

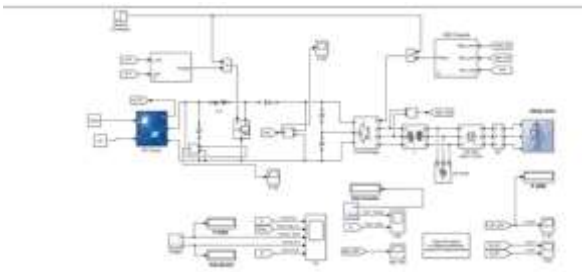

Figure 2: Simulation circuit of the proposed system

The technical specifications of the solar panel used for the simulations are shown in the figure below.

Figure 3: Technical specifications of the PV Grid.

The voltage and current transition graphs after the simulations are run in MATLAB software are shown in the below figure.

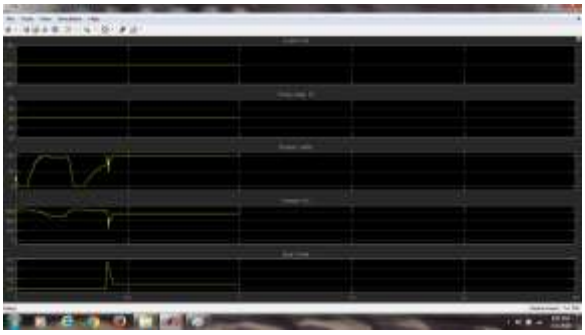

Figure 4: Voltage, current transition in solar PV.

Figure 5: Power and modulation index transition at the inverter.

Figure 6: Power transition at utility Grid

From the above graphs, it is shown that the various conditions proposed are checked and their results verified.

CONCLUSION

Thus, the proposed design of closed-loop grid-connected converters for solar rooftop systems with net metering using fuzzy logic provides an efficient and feasible solution for the rooftop solar system problems in India. The bidirectional movement of power, that is the import and export of power automatically through net metering makes this an ideal system for future implementation in the urban and suburban regions of India. Further features such as the Internet of Things and cloud computing can be utilized to take this proposed system even further.

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