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DESIGN AND IMPLEMENTATION OF BUCK CONVERTER USING PD-FUZZY CONTROLLER

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Abstract: The main aim of this paper is to analyze the output response of buck converter by the analysis of deportment and performance of Proportional Derivative Controller and Fuzzy Logic Controller in terms of settling time, percentage overshoot and robustness. The output response of converter is obtained and compared with the help of simulation software named as MATLAB and Simulink. The frequency response of buck converter is required for designing of PD controller whereas fuzzy logic algorithm developed based on some expert knowledge or trial and error method for designing of the FLC. The DC-DC converters are widely used in photovoltaic generating systems as an interface between PV module and the load. These converters must be chosen to be able to match the maximum power point (MPP) of PV module when climatic conditions change with different resistive load values. So, DC-DC converters must be used with MPPT controller in order to reduce losses in the global PV system. The nonlinear power characteristic of PV greatly depends on the environmental conditions. Hence in order to draw maximum available power, various algorithms are used with PV voltage/current or both as an input for the maximum power point tracking (MPPT) controller. Non-isolated DC-DC converters with high voltage gain are desired in all photovoltaic (PV) energy conversion systems. The buck converter provides the high voltage transfer which enables the high power PV system to work with low size inductors with high efficiency. The balancing of the voltage across the two capacitors of the converter and MPPT is achieved using a simple duty cycle based voltage controller. The validation of the proposed system is done by the experiments carried out on simulation with PD – fuzzy logic controller as a core controller. The proposed system will suit as one of the solutions for PV based generation system and will show high performance, such as a conversion efficiency of up to 94% for modern aircraft application.

Index Terms - Maximum Power Point Tracking (MPPT); Proportional Derivative (PD); Pulse Width Modulation (PWM); Distribution Static Compensator (DSTATCOM); Synchronous Reference Frame (SRF).

1. INTRODUCTION

The world's energy consumption is increasing by about 3.5% annually and is expected to rise further because of population growth and demanding modern lifestyles. The increased energy demand results in rapid depletion of conventional fossil fuels and adds to the existing consequences of the environmental pollution. Solar energy for all practical purposes as a source of energy, is inexhaustible, absolutely free (in terms of its availability), quiet, and environmentally friendly. In order to reduce the overall cost of PV systems, therefore, these are utilized effectively with interface to the existing systems through DC-DC converters. The major challenge is to extract the power under varying operating conditions which influence the output voltage extraction of the maximum power from a solar cell turns out to be a vital consideration for optimal system design. Under fluctuation of climatic conditions, MPP changes and MPPT must adjust the converter duty cycle to track the new MPP. Therefore, the DC-DC converter must be chosen to be able to match the MPP under different atmospheric conditions.

Objectives

When the duty cycle changes as a result of changed climatic conditions, the boundary of the converter design parameters will change. Isolated converter structures with cascaded configuration enables to achieve high voltage gain. The buck converters have significant advantage as compared to conventional converter. The size of the inductor is reduced and switch voltage rating is half of the output voltage. This reduces the overall size and improves the efficiency in proposed converter. The fundamental problem addressed by MPPT is to produce maximum output power under a given temperature and irradiance. Various algorithms for MPPT are reported in the literature and used for the efficient energy conversion process. These methods are derivative based and noise sensitive. An efficient algorithm is having noise and signal fluctuation immunity with fast convergence as compared to many reported MPPT method is proved in this paper

Scope of the project

The major challenge is to extract the power under varying operating conditions which influence the output voltage extraction of the maximum power from a solar cell turns out to be a vital consideration for optimal system design. Under fluctuation of climatic conditions, MPP changes and MPPT must adjust the converter duty cycle to track the new MPP. Therefore, the DC-DC converter must be chosen to be able to match the MPP under different atmospheric conditions.

2. Existing and proposed system

2.1 Existing system

The modern aircraft's electrical generation and conversion efficiencies are slightly more than that of the existing aircraft electrical system. The pilot's cabin communication and electronic devices are fed by 28V DC bus system and they are connected with batteries to operate under emergency conditions. In order to get 28V DC from 400V AC a three-phase bridge rectifier with forward buck converter is provided. The PID-FLC based control is used for controlling the forward buck converter. The voltage at 28V DC is simulated and the results are obtained.

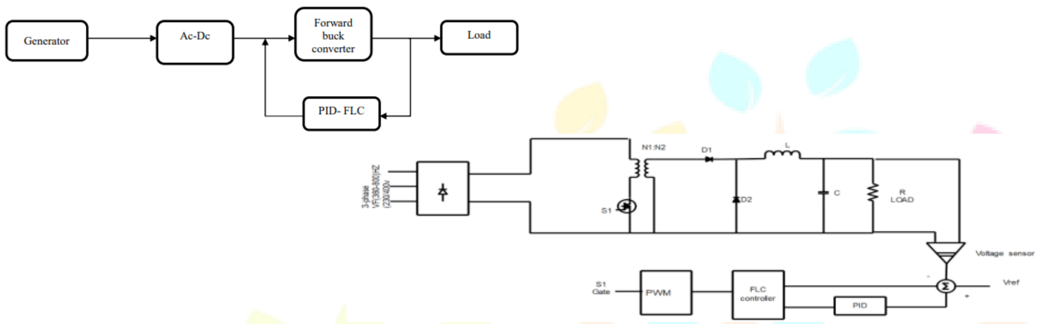


Fig.1: Block Diagram of Existing System

2.2 Mae generator operation

The modern aircraft is provided with two three-phase synchronous generators, placed on each side of the aircraft. Every synchronous generator provides a total output power of 250 KVA with a Line - Line output voltage of 400 VLL and the range of frequency is from 360 Hz to 800 Hz. Apart from generators, there exists two auxiliary power units (APUs), with their ratings similar to the main generators except that their output power from each unit is 225 VA. These APUs will operate only under emergency conditions such as during the failure of the main generators. The PID based Fuzzy logic control is given to provide suitable excitation voltage for the GCU to maintain the output voltage of the generator within the aircraft standards whenever the engine speed or electrical load changes.

2.3 Forward buck converter

The Forward converter is one of the most important and popular switched mode power supply (SMPS) circuit capable of developing isolated and controlled dc voltage from an unregulated dc input. As in fly-back converter, the dc voltage at the input is derived after rectification with little filtering of the utility ac grid voltage. When compared to the fly-back circuit, the forward converter has more efficiency in terms of energy and is used for applications requiring high power output. However, in terms of the circuit topology, especially the filter at the output is not as simple as in the case of fly-back converter. This forward converter has a fast switching device 'S' with its own control circuit, a transformer with its primary side connected in series with switch 'S' to the input side and a rectification and filtering circuit is connected to the secondary winding of the transformer. Across the rectified output of the transformer-secondary winding the load is connected.

2.4 Proposed system

To maintain DC bus voltage constant, in high power rating PV systems with high voltage gain requires buck converter with controller. Interfacing PV with buck converter having wider range of voltage level is preferred due to reduce input filter size and current ripple cancellation.

This converter has increased power density, efficiency, and reduction in cost as the switching device's voltage rating is half of the output voltage. As the capacitors $C1$ and $C2$ are equal, voltage of the centre point is $Vo/2$. This also reduces the voltage stress across the switching devices in these converters.

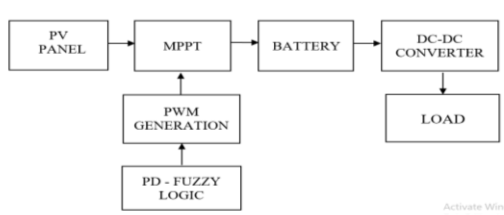


Fig.2: Proposed Block Diagram

2.5 Photovoltaic cell

Conversion of light energy in electrical energy is based on a phenomenon called photovoltaic effect. When semiconductor materials are exposed to light, the some of the photons of light ray are absorbed by the semiconductor crystal which causes a significant number of free electrons in the crystal. This is the basic reason for producing electricity due to photovoltaic effect. Photovoltaic cell is the basic unit of the system where the photovoltaic effect is utilized to produce electricity from light energy. Silicon is the most widely used semiconductor material for constructing the photovoltaic cell. The silicon atom has four valence electrons. In a solid crystal, each silicon atom shares each of its four valence electrons with another nearest silicon atom hence creating covalent bonds between them. In this way, silicon crystal gets a tetrahedral lattice structure. While light ray strikes on any materials some portion of the light is reflected, some portion is transmitted through the materials and rest is absorbed by the materials.

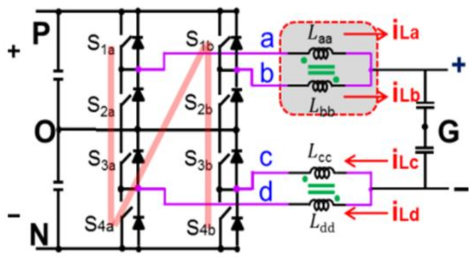


Fig.3: DC/DC Converter with coupled inductors

2.6 Fuzzy controller

Accuracy to ambiguity is called as fuzzy; It is working on probability concept. It is defined as a control logic that pretends to use degrees of input and output to estimate human reasoning with the integration of rule-based implementation. The technique used in the manipulation of undesired information or facts which involves some degree of uncertainty.

It consists of 4 major parts

1. Fuzzifier.
2. Rules.
3. Inference Engine.
4. DE fuzzifier.

Working:

Fuzzy is nothing but the technique working with the set concepts and the assumptions are made to finalize the output. Fuzzy set have a choice of values of {0, 1} and it's working with the fuzzy rules, it may be an if-then rule. Based upon the rule concept, way of thinking is the important part of the fuzzy to provide 1 for the correct value and 0 for a fake value as well as ambiguity for unfair values. All these fuzzy actions grouped together to form a system output.

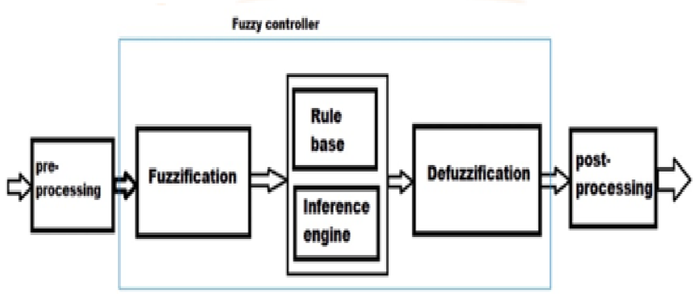


Fig.4: Fuzzy Controller Block Diagram

3. Software requirement

MATLAB Software is used in this Simulation. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages. Identifying System Components, three types of components define a system:

- Parameters — System values that remain constant unless you change them.
- States — Variables in the system that change over time.
- Signals — Input and output values that change dynamically during a simulation.

3.1 Simulation

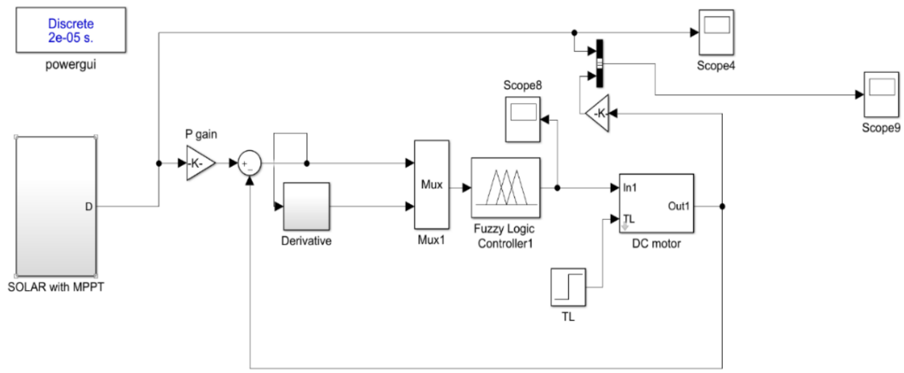


Fig.5: Overview

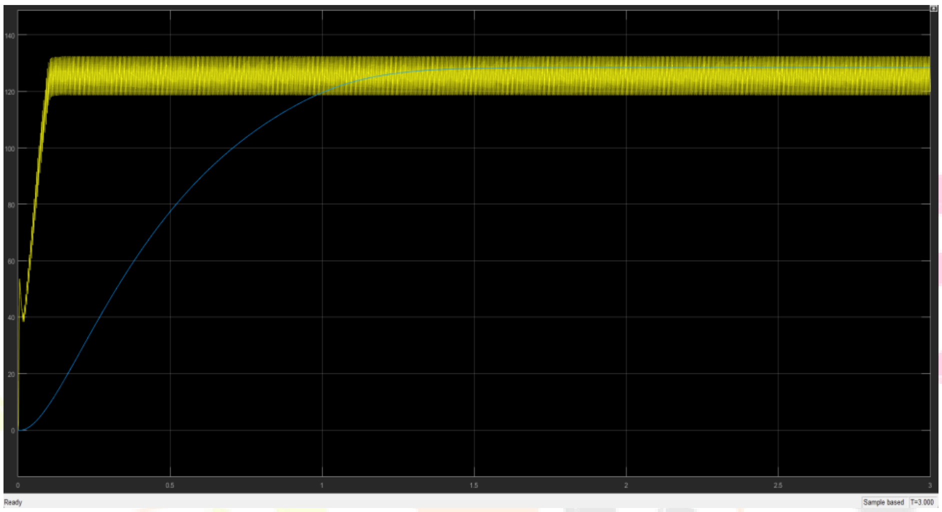
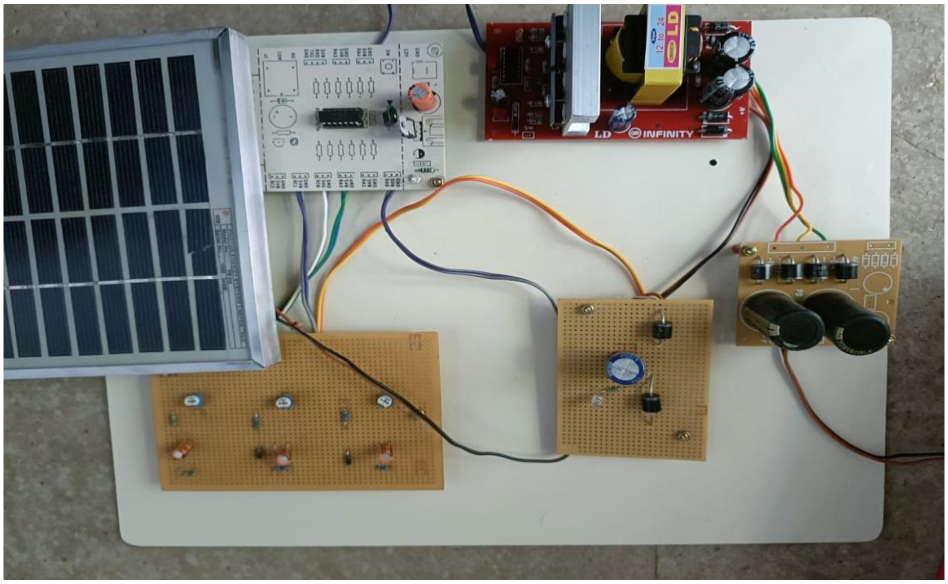


Fig.6: Model Waveform

3.2 Hardware



Conclusion

In this project, Analysis of buck converter is used to interface the PV system for maximization of the power extraction. Various maximum power point tracking algorithms- PD – Fuzzy logic is verified in the software and found that it shows better dynamic response with the faster convergence without any oscillations while tracking. The voltage balancing is executed through the PD - fuzzy controller and performance is observed to be satisfactory.

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