

Original Article

Super Capacitor Assisted Technique for Reducing Losses in the Input Loop of an Inverter System for Solar PV Application

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Abstract: In solar photovoltaic (PV) inverter systems, power losses in the input loop significantly impact overall efficiency and performance. This paper presents a Super Capacitor Assisted (SCA) technique to minimize conduction and switching losses in the input stage of an inverter system for solar PV applications. By integrating supercapacitors strategically within the power circuit, the proposed method reduces peak current stress, stabilizes voltage fluctuations, and enhances transient response. The project provides a detailed analysis of the working principle, power loss reduction mechanisms, and the design considerations for implementing the SCA technique. A prototype system is developed and tested to validate the effectiveness of the proposed approach. Experimental results demonstrate a notable improvement in efficiency, reduced thermal stress on semiconductor devices, and enhanced reliability of the inverter system. The findings highlight the potential of supercapacitor assisted techniques as a viable solution for next-generation high-efficiency solar PV inverters, ensuring better energy utilization and prolonged system lifespan.

Keywords: Supercapacitor, Solar Photovoltaic (PV) System, Inverter Efficiency, Power Loss Reduction, DC/DC Converter, Voltage Stability, Embedded Controller, Energy Storage, Renewable Energy Integration, PWM Control, Grid Voltage Regulation, Smart Inverter Design, Transient Response Enhancement, Conduction and Switching Losses, High-Efficiency Power Conversion.

I. INTRODUCTION

The integration of renewable energy sources, particularly solar photovoltaic (PV) systems, into power grids has become a cornerstone of modern energy strategies. Solar PV systems offer a sustainable and environmentally friendly alternative to fossil fuels, but their increasing penetration into power grids presents unique challenges, especially concerning voltage stability. This project explores the dynamics of power grid voltage stability in the context of high solar PV penetration, aiming to address the technical, operational, and economic aspects of this transition.

A. The Rise of Solar PV in Power Grids

The global shift towards renewable energy has been driven by the need to reduce greenhouse gas emissions and combat climate change. Solar PV systems have emerged as a leading renewable energy source due to their scalability, declining costs, and minimal environmental impact. However, the intermittent nature of solar energy, influenced by factors such as weather conditions and diurnal cycles, poses challenges for maintaining grid stability. This section delves into the growth of solar PV installations and their implications for power grid operations.

B. Voltage Stability Challenges

Voltage stability is a critical aspect of power grid reliability. High penetration of solar PV systems can lead to fluctuations in voltage levels, especially during periods of rapid changes in solar irradiance. These fluctuations can affect the performance of electrical equipment, disrupt grid operations, and even lead to blackouts. This section examines the technical challenges associated with voltage stability, including reactive power management, load balancing, and the impact of solar PV variability.

C. Technological Solutions and Innovations

To address the challenges of voltage stability, various technological solutions have been developed. These include advanced inverter technologies, energy storage systems, and grid-supportive control mechanisms. This section highlights the role of these innovations in enhancing grid stability and ensuring seamless integration of solar PV systems. Case studies of successful implementations in different regions are also discussed.



II. SYSTEM IMPEMETATION

A. Existing System

The existing systems that address power grid voltage stability focus on integrating advanced technologies to manage challenges. Grid-connected systems are designed to maintain stability through reactive power compensation and voltage regulation. Energy storage solutions, such as batteries, are essential for balancing demand and supply by storing excess energy during low demand and releasing it when needed. Advanced inverter technologies help regulate voltage and frequency, improving grid stability. Smart grid technologies use modern communication and control systems to monitor and manage voltage issues in real time.

B. Proposed System

In this project to control the voltage load side and source side by using renewable energy sources. Renewable energy we used solar panel. Solar panels use light energy (photons) from the sun to generate electricity through the photovoltaic effect. To sense the voltage in source and load side by using potential transformer. The output of potential transformer is given to voltage measurement unit. It is used to measure the voltage, and is given to controller. In this project we use embedded controller. It is used to monitor the source and load voltage. When the source and load voltage is not equal, the controller give the PWM signal to gate driver. Gate drive to operate the DC/ DC converter. DC to DC converter, to boost the voltage from solar panel, and is given to inverter. Inverter is used to invert the voltage in DC to AC, and is given to load to control the voltage sag. To give the trigger pulse in inverter by using gate driver. It is controlled by Controller and buffer.

C. Block Diagram

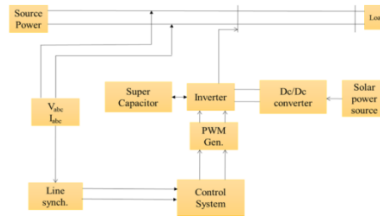


Figure 1: Proposed Block Diagram

D. Block Description

The source power serves as the main supply of electrical energy to the system, ensuring continuous power delivery to the load and other components. It provides the required voltage (V_{abc}) and current (I_{abc}) for operation while supporting stable and reliable power flow. The control system monitors these parameters to optimize performance and balance energy distribution. Additionally, it interacts with other components, such as the supercapacitor and solar power source, to enhance efficiency and power stability. The load represents the final consumer of electrical energy in the system, which can be industrial machinery, household appliances, or commercial equipment. To ensure uninterrupted operation, the control system dynamically adjusts power flow to meet varying load demands. If the primary power source is insufficient, additional power is supplied from the supercapacitor or solar source. Effective load management prevents overloading and enhances the overall efficiency of the system. The supercapacitor acts as a high-speed energy storage device that compensates for sudden power demand fluctuations. It rapidly discharges energy when additional power is required and recharges when surplus energy is available. This capability makes it essential for stabilizing voltage fluctuations and improving the reliability of power delivery. Integrated with the inverter and controlled by the system, it helps in smoothing transient loads and enhancing overall system stability. The solar power source introduces renewable energy into the system, reducing dependence on conventional power sources. It generates DC electricity, which is processed through a **DC/DC converter** to ensure compatibility with other system components.

E. Circuit Diagram

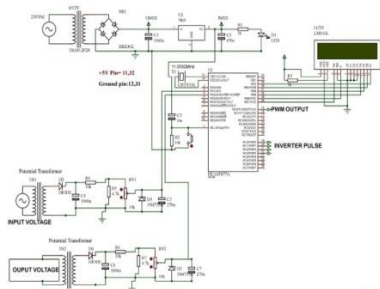


Figure 2: Microcontroller Unit with Voltage Measurement Unit

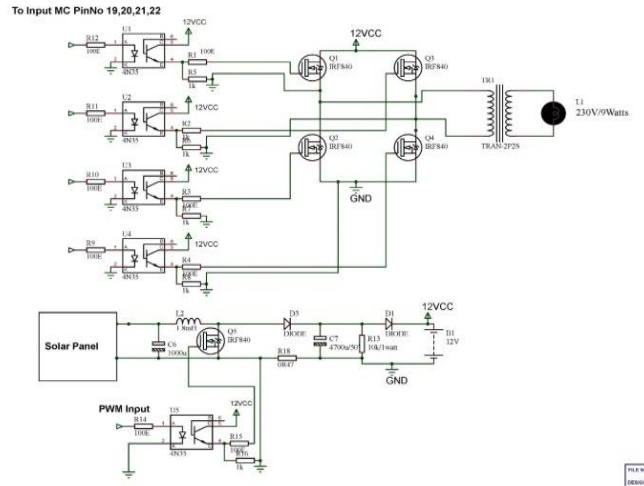


Figure 3: PV with Inverter Unit

F. Circuit Description

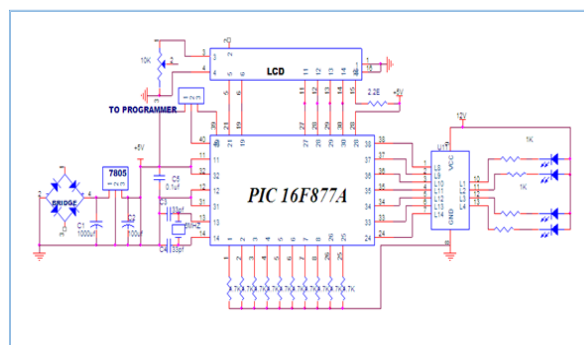
The provided circuit diagrams illustrate a solar inverter system and its control circuitry. The solar inverter circuit converts solar energy into usable AC power, utilizing components such as MOSFETs, optocouplers, a transformer, a solar panel, resistors, capacitors, diodes, PWM input, and an AC load. The microcontroller-based inverter control circuit manages the inverter's operation with a PIC16F877A microcontroller, an LCD display, a crystal oscillator, a bridge rectifier, voltage regulators, resistors, capacitors, diodes, potential transformers, a transformer, and potentiometers. The voltage measurement unit are connected to pin 3,4. Key connections in the microcontroller include the VDD pins (11, 32) for positive supply voltage, VSS pins (12, 31) for grounding, OSC1/CLKIN (13) and OSC2/CLKOUT (14) for clock input and output, PORTE pins (8, 9, 10) as general-purpose input/output pins, and the MCLR/VPP pin (1) for the master clear (reset) function. These components and connections work in unison to efficiently convert and manage solar energy, providing a stable and reliable power supply.

III. HARDWARE DETAILS

A. Micro Controller Pic16f877a

a) Pic Controller Circuit Diagram

- PIC 16F877 is one of the most advanced microcontroller from Microchip. This controller is widely used for experimental and modern applications because of its low price, wide range of applications, high quality, and ease of availability. It is ideal for applications such as machine control applications, measurement devices, study purpose, and so on.

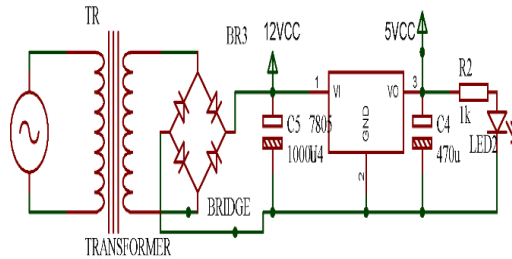


b) Pheripheral Features

- Timer 0: 8 bit timer/counter with 8 bit prescaler.
- Timer 1: 16 bit timer/counter with prescaler, can be incremented during via external crystal/clock
- Timer 2: 8 bit timer/counter with 8 bit period register, prescaler and postscaler.
- Two captures, compare, PWM modules capture is 16 bit, max. resolution is 12.5 ns compare is 16 bit max.resolution is 200ns
- PWM mod. Resolution is 10bit
- 10 bit multichannel Analog to digital converter.
- Universal Synchronous Asynchronous

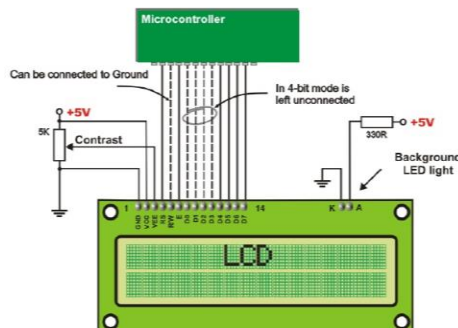
B. Single Power Supply

Power supply gives supply to all components. It is used to convert AC voltage into DC voltage. Transformer used to convert 230V into 12V AC. 12V AC is given to diode. Diode range is 1N4007, which is used to convert AC voltage into DC voltage. AC capacitor used to charge AC components and discharge on ground. LM 7805 regulator is used to maintain voltage as constant. Then signal will be given to next capacitor, which is used to filter unwanted AC component. Load will be LED and resistor. LED voltage is 1.75V. If voltage is above level beyond the limit, and then it will be dropped on resistor.



C. LCD Display

Liquid Crystal Displays (LCDs) have materials, which combine the properties of both liquid and crystals. Rather than having a melting point, they have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered form similar to a crystal. An LCD consists of two glass panels, with the liquid crystal material sandwiched in between them. The inner surface of the glass plates are coated with transparent electrodes which define the character, symbols or patterns to be displayed. Polymeric layers are present in between the electrodes and the liquid crystal, which makes the liquid crystal molecules to maintain a defined orientation angle. On each polarizer is pasted outside the two glass panels. This polarizer would rotate the light rays passing through them to a definite angle, in a particular direction. When the LCD is in the off state, light rays are rotated by the two polarizer and the liquid crystal, such that the light rays come out of the LCD without any orientation, and hence the LCD appears transparent. When sufficient voltage is applied to the electrodes, the liquid crystal molecules would be aligned in a specific direction.



The LCDs are lightweight with only a few millimeters thickness. Since the LCD's consume power, they are compatible with low power electronic circuits, and can be powered for long durations. The LCD does not generate light and so light is needed to read the display. By using backlighting, reading is possible in the dark. The LCD's have long life and a wide operating temperature range. Changing the display size of the layout size is relatively simple which makes the LCD's more customers friendly. The LCD's used exclusively in watches, calculators and measuring instruments are the simple seven-segment displays, having a limited amount of numeric data. The recent advances in technology have resulted in better legibility, more information displaying capability and a wider temperature range. These have resulted in the LCDs being extensively used in telecommunications and entertainment electronics. The LCDs have even started replacing the cathode ray tubes (CRTs) used for the display of text and graphics, and also in small TV applications.

D. Solar Panel



Solar energy begins with the sun. Solar panels (also known as "PV panels") are used to convert light from the sun, which is composed of particles of energy called "photons", into electricity that can be used to power electrical loads. Solar panels can be used for a wide variety of applications including remote power systems for cabins, telecommunications equipment, remote sensing, and of course for the production of electricity by residential and commercial solar electric systems.

IV. RESULTS

Hardware setup and output are show below:

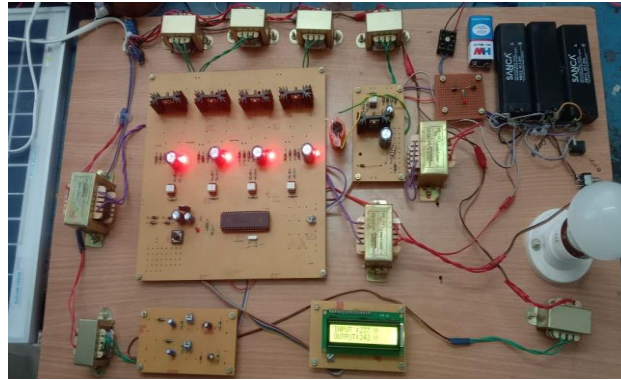


Figure 4: Hardware Setup

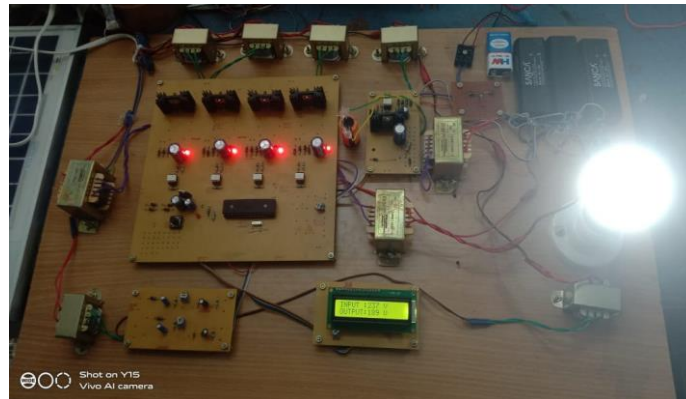


Figure 5: Load Turns on When the Voltage Less Than 200v



Figure 6: Result with Optimal Output Voltage Result

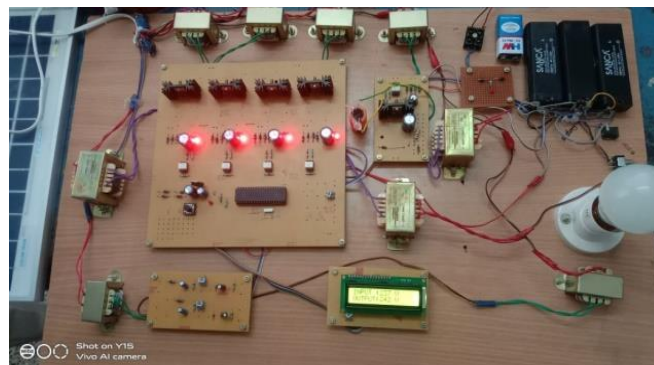


Figure 7: When Out Voltage is higher than 200v Load Get Turned Off



Figure 8: Result with High Output Voltage Result

V. CONCLUSION

In conclusion, this project addressing power grid voltage stability with high penetration of solar photovoltaic (PV) systems demonstrates the importance of adapting power grids to meet the challenges posed by renewable energy integration. Solar PV systems, while providing clean and sustainable energy, introduce variability that can affect grid voltage stability. However, with advanced technologies such as energy storage systems, smart grid solutions, and modern inverter designs, these challenges can be effectively mitigated.

VI. REFERENCE

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