Journal of Science Engineering Technology and Management Science
Volume 02, Issue 05, May 2025 *ISSN: 3049-0952*
www.jsetms.com *DOI:10.63590/jsetms.2025.v02.i05.pp01-06*

VSI-Based Single-Stage PV-Grid System with a Basic Control Circuit

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To Cite this Article
Hima Bindu and Someshwar, "VSI-Based Single-Stage PV-Grid System with a Basic Control Circuit", Journal of Science Engineering Technology and Management Science, Vol. 01, Issue 01, November 2024, pp: 01-06, DOI: http://doi.org/10.63590/jsetms.2025.v02.i05.pp01-06
Submitted: 14-02-2025 *Accepted: 24-04-2025* *Published:02-05-2025*

Abstract*: Implementations that connect PV-produced electricity to utility networks have been successfully designed. The existing systems employ single-stage converters or divided their conversion process into two stages. The first converter stage operates as MPPT for PV power optimization whereas the second stage functions as utility interface in two-stage converter systems. The single-stage converter system enables operation of an inverter which performs both functions for the system. A PV-Grid infrastructure with a single-stage voltage source inverter system serves as the main suggestion of this research. A basic control circuit enables both maximum PV power generation and equalizes the power output between PV and inverter systems. The analysis requires simulation testing that confirms its validity.*

Keywords*: Grid, Inverter, Photovoltaic, Maximum Power Point, and Equilibrium Power*

I. Introduction

Solar energy presents itself as a viable alternative option because of worldwide petroleum issues as well as rising environmental worries. Photovoltaic (PV) systems serve as popular direct converters of solar energy into electrical power during the present era. The connection of nonlinear loads to PV devices stops the PV from generating its maximum possible output power. The expense of PV arrays constitutes a major component of this issue. PV implementation needs to show its effectiveness since this will reduce the overall cost thus making PV operate at full power. An application requires the use of MPPT (Maximum Power Point Tracker) devices to make PV systems operate at their maximum possible power output.

PV installations require two main categories which are standalone and grid-connected systems. Systems with isolated PV dependence constitute the initial segment while PV and grid integration systems represent the second grouping. Research focusing on PV-grid connected systems grows intensely due to rapid power conditioning developments. The application sector shows specific advantages among other benefits. The integration of utilities with PV systems should not compromise the peak operating efficiency of the PV system. Cascading two converters allows PV-grid systems to use MPPT DV-DC converter alongside the DC-AC converter for grid connection.

To operate correctly in PV-grid systems utilizing a single stage converter the DC-AC converter performs the role of Maximum Power Point Tracker (MPPT). A modification of the incremental conductance-based control for three-phase inverters enables the system to raise stability standards when constructed using DSP hardware for PV-grid applications. Sliding mode acts as an underlying principle to develop other control methods. Fuzzy logic enables Paper [7] to enhance the response speed of three-phase inverters.

The implementation of DSP technology and similar digital equipment needs sophisticated hardware processors along with demanding algorithms for operation. The research proposes a PV-grid system featuring a single-phase voltage source inverter instead of the systems mentioned previously. The implementation uses control parameters which integrate both hysteresis principles and modified hill-climbing behavior. Power balance serves as the control objective through a method that makes the inverter output power average match the maximum PV power production. Verification of the analysis takes place through simulation tests.

II. Research Method

A thorough theoretical discussion of PV power theory combined with power equilibrium theory and Figure 1 system depiction serves to explain the proposed single-stage PV-Grid System. PV generates its maximum power output (P_{MPP}) only when operating at voltage value (V_{MPP}) while drawing current value (M_{PPI}). The specified numbers exist within specific ranges which depend both on temperature and irradiation levels. The PV module operates at its operational point through direct load connection at the point where I-V characteristic curve intersects the load line.

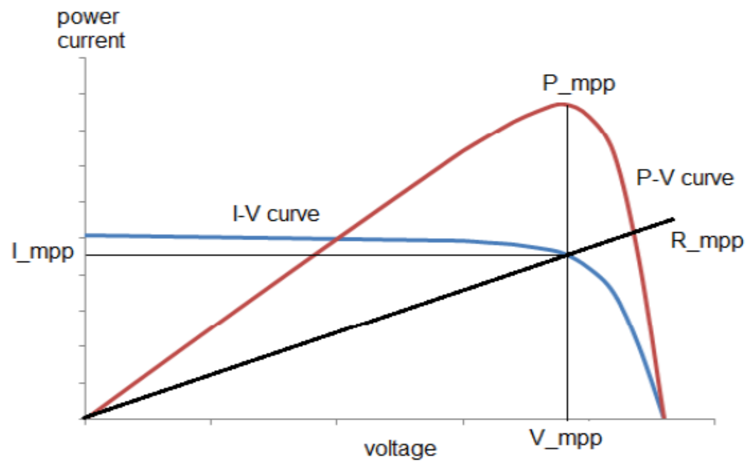

Fig 1: Characteristic curve of a PV (a) V-I curve (b) V-P curve

A conversion from PV module produced direct current to alternating current requires an inverter unit. One necessary condition when linking this inverter to grid voltage is the requirement of output voltage match between the inverter and the grid. The inverter output voltage becomes automatically tied to grid voltage when used as a regulated current source. For this inverter to distribute all PV module-generated power toward the grid it must produce equivalent average power output as the PV modules run at their maximum point. Figure 2 illustrates the block system composed of PV modules, an inverter as well as grid power connection.

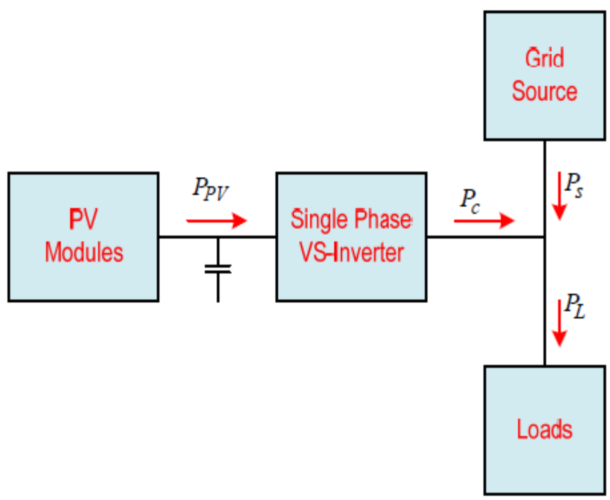

Fig 2: Block system of PV-Grid with single stage inverter

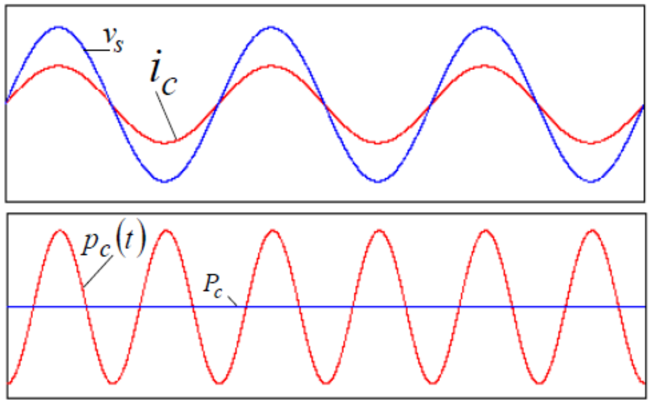

Fig 3: Instantaneous values of voltage, current and power

Under normal irradiation and temperature conditions the inverter output current determines when PV modules produce maximum power according to equation (7). A transition of PV operating point arises due to modifications in this current value. The system requires a controller which tracks power point locations to redirect them toward MPP in order to maintain PV module operating points near their MPP conditions. Among all power comparison factors the first power measurement operates immediately while the second power measurement functions as a statistical average.

The controller needs a capacitor placed between PV modules and the inverter to function as required in an immediate state. The stored capacitor energy will discharge as the inverter instantaneously generates more power than the photovoltaic system does. Power flows from the PV to the capacitor when the inverter instantaneously produces output power lower than what the PV generates. Figure 4 presents the designed single-phase, single-stage PV-Grid system.

The PV modules receive their power connection from a capacitor that serves as the input component of a voltage source inverter. Learning MPPT concepts allows users to maximize the electrical output of PV modules. This paper applies the modified hill-climbing innovation to its analysis. The PV system needs measurements of its voltage along with current values. A voltage source inverter combines with a regulated current source functionality to enable grid connection as shown in Figure 5. This inverter type becomes possible through detecting its output current.

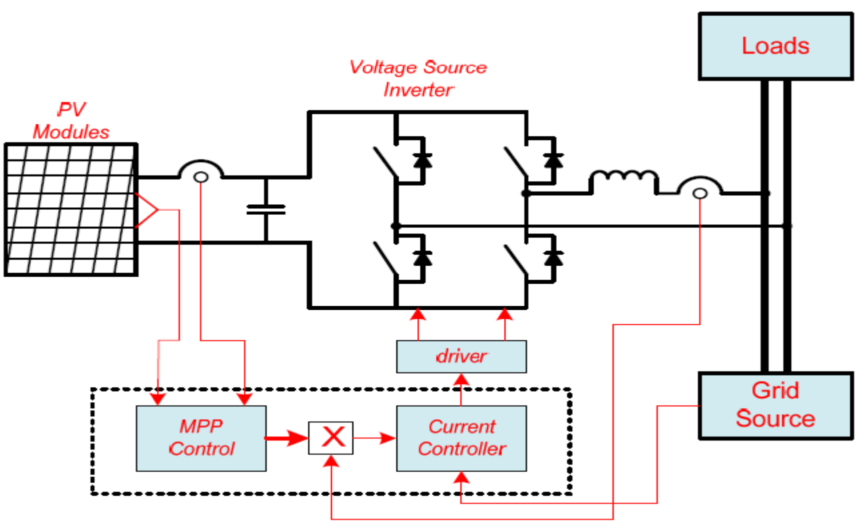

Fig 4: Proposed Scheme

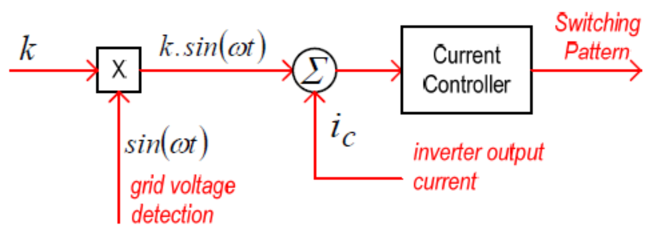

Fig 5: Current controller scheme

III. Results and Analysis

Computer-based simulations serve the purpose of validating the previously mentioned analysis. A simulation scheme presented in Figure 4 enables PSIM-based operation. The PV-inverter receives power from the AC system with resistive loads which constitute the grid. The connection of three series-configured 60 W_p PV modules allows the system to deliver output voltages higher than the grid voltage.

The simulation experiment includes two cases, 1000 W/m^2 and 500 W/m^2. A specific power flow occurs to the grid and the current phase measures 180 degrees relative to voltage as PV power generation exceeds load absorption during 1000 W/m2 irradiance conditions. The inverter output generates instantaneous power from zero to its maximum limit which produces an average power equivalent to PV-generated power because both voltage and current waves are sinusoidal with identical phase. The power homeostasis between the inverter system and the provided PV depends critically on the input capacitors of the inverter.

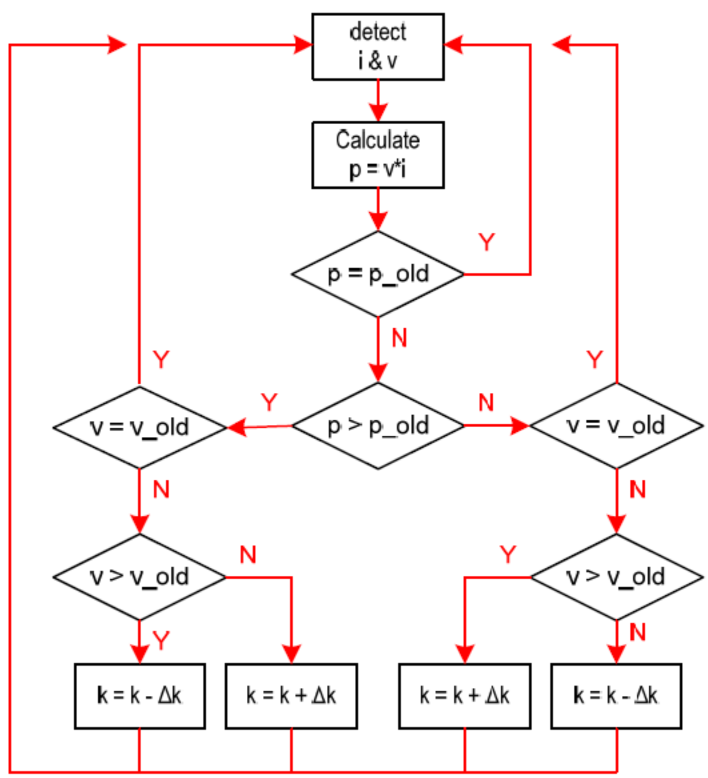

Fig 6: Flowchart of the control scheme in K factor variation

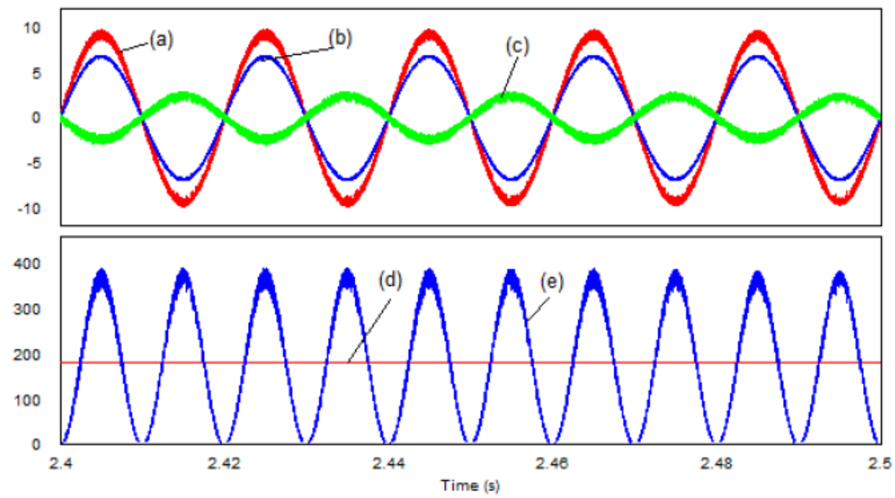

Fig 7: Simulated waveforms under irradiance 1000W/m2 (a) inverter output current (b) load current (c) grid current (d) PV maximum power (e) inverter output power

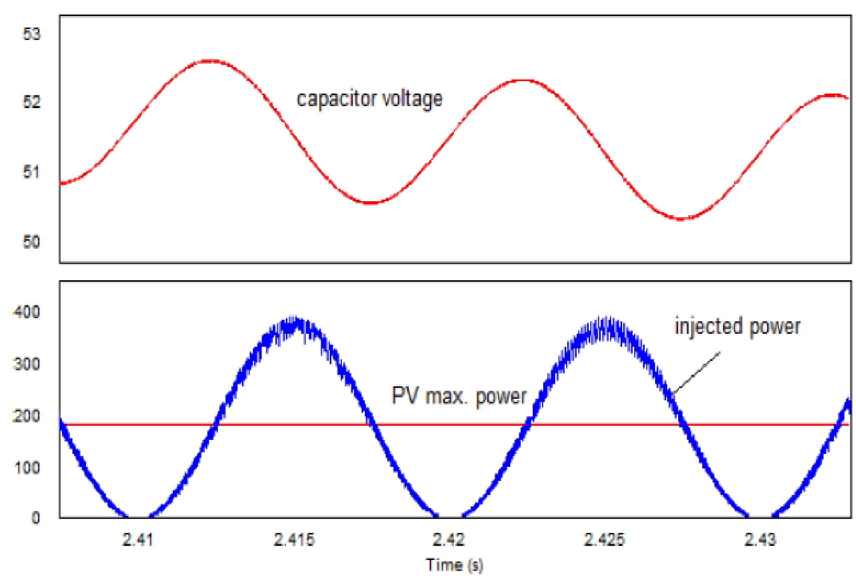

Fig 8: Capacitor voltage variation with respect to comparation between the values of P_{PV} and p_c

IV. Conclusion

Research regarding a single-stage PV-Grid system completed its analysis and description using a single-phase VSI. The control plan implementation for the inverter obtains its structure from analytical findings to achieve optimal PV power generation and grid power transfer. Through its proposed design the control system successfully meets the required operational needs. The simulation results show maximum power output occurs when the solar radiation reaches its peak level. The Voltage Source Inverter makes it possible to supply the maximum power available from the grid. Even as solar irradiation drops the inverter keeps providing electrical energy to the grid at the entire PV power capacity.

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