Five- level Grid Synchronized PV Inverter with MPPT for Micro-Grid Application

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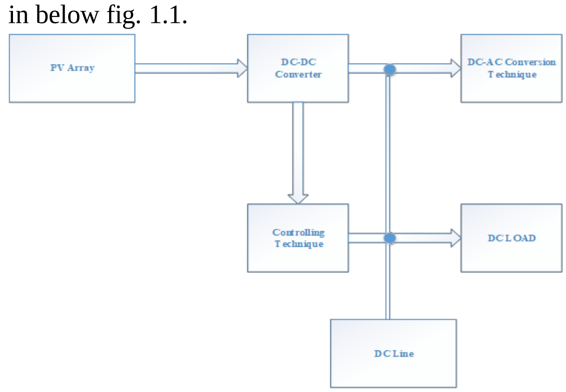
***Abstract*— This paper reveals a Five-level inverter topology for photo-voltaic (PV) power generation system. The 7- level inverter created by cascading single phase full and half bridge inverter topology sustained with three separate PV strings. The output has 5-levels: +Vdc, +2/3Vdc, +Vdc/3, 0, Vdc/3, -2Vdc/3, -Vdc. The 5-level inverter function is possible by using seven semic onductor switches. The designed inverter configuration has able to maintain consistent operation as inverter even though there is source and semiconductor switch breakdown. The developed inverter is differentiating with conventional multilevel inverters in terms of number of components, losses and reliability. The result of a 5-level inverter topology is confirmed by using MATLAB/SIMULINK software.**

***Index Terms*—5-level inverter, PV generation system, reliability, P&O, PV Grid, MATLAB /SIMULINK**

I. INTRODUCTION

As the energy demand is increasing day by day due to industrialization and population growth, people are investing in alternate energy solutions to meet those energy requirements thereby improving energy efficiency and power quality issues. In this technical era, renewable energy resources are playing revealingly progressing role in electricity generation. Many types of renewable resources such as solar (PV Cell) energy, geothermal, wind energy etc are exploiting for electric power generation. The main challenge in substitute running systems with newer more environmentally friendly alternatives is how to generate the maximum power and deliver the maximum power at a minimum reliable cost for a given load. Photovoltaic power generation is growing very fast. The use of photovoltaic energy is considered to be a primary resource, because there are several countries located in tropical and temperate regions, where the direct solar density may reach up to 1000 W/m^2.The solar energy received by the earth from the sun is so boundless that the total energy consumed annually by the whole world is supplied in as short interval of time as in half an hour The efficiency may be decrease due to other factors like load conditions and temperature of solar panel. Therefore, Maximum Power Point Tracker (MPPT), by providing its maximum power to the PV system and as an energy storage element helps in extracting more stable and reliable power from the PV system for both load as well as utility grid and hence improves the steady and dynamic behavior of the whole system.

The proposed model, the entire components and control systems are simulated under MATLAB/Simulink Software. Block diagram of developed hybrid generation system has been given in below fig. 1.1.



II. PROCEDURE FOR PAPER SUBMISSION

A. METHODOLOGY

The modeling and simulation of the equivalent circuitry is done at once in the second stage. The following three figures namely fig. 2.1, fig. 2.2 elaborates the complete methodology of developed hybrid generation system using flowchart.

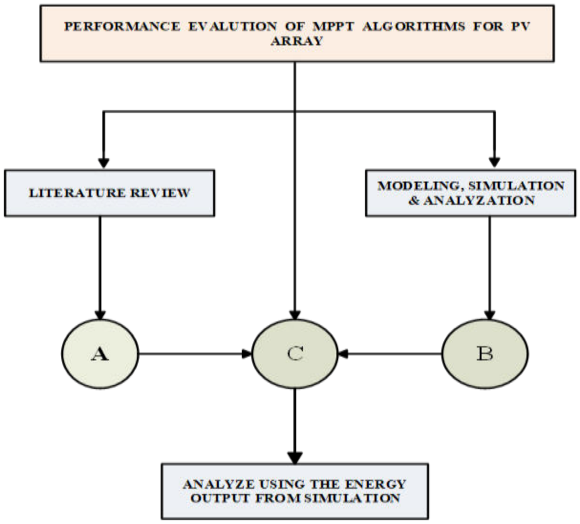


Fig.2.1 Methodology flowchart

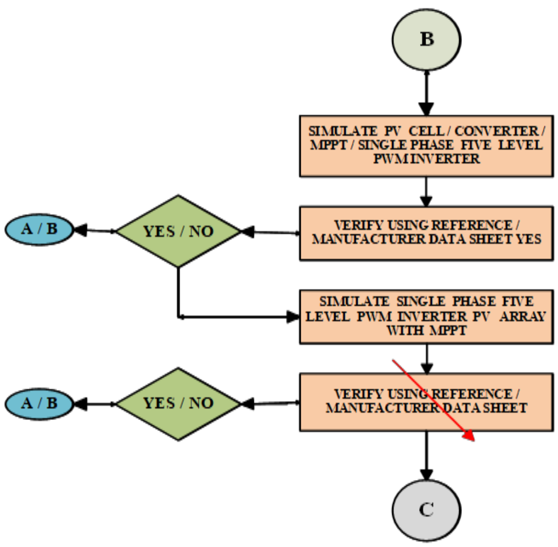


Fig.2.2 Flowchart for Simulation

B. Fundamentals of PV System & Their Components

Photovoltaic cells are electronic devices that are capable of generating electricity from a light source by the photovoltaic effect. An electric current generated when photons in light hit the photovoltaic cell and absorbed by the semiconducting material. After absorption, electrons knocked loose from the atom and passage through the material, generating an electric current. Photovoltaic cells, or solar cells, typically arranged in two forms:-

Photovoltaic Module

Two or more interconnected cells encapsulated in a weatherproof material. The cells connected in series to increase the voltage output or in parallel to increase its current output. A single cell has a relatively low voltage handling capability on the order of 0.57 Volt at . While a multiformity of connection schemes present for a multitude of applications, a common scheme for P-V modules used in power generation is a connection of 36 or 72 cells in series.

Photovoltaic Array

A photovoltaic array is composed of series and parallel connections of solar modules. Two or more interconnected modules connected in series to increase the voltage output or in parallel to increase its current output. Grid connected systems require an inverter which in order to successfully interface with the grid requires a specific DC input voltage range generally on the order of 200-600 Volts DC. PV arrays are designed to generate a voltage close to the top of this range at rated power generation. This permits the inverter to operate for the maximum possible range of DC voltage input and therefore the maximum range of environmental conditions. Once the voltage requirement is met, power handling capability can be raised by connecting additional module strings in parallel.

C. Circuit Model for PV Cell & Their Characteristics

Actually SPV array is made of many SPV cells. The several SPV cell makes the SPV module and many module makes the SPV array connected series and parallel and then it have ready for using .The basic electrical equivalent circuit of SPV

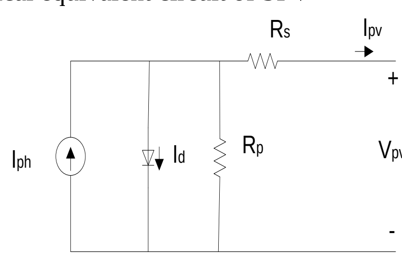


Fig.2.3: Basic equivalent circuit of solar photovoltaic (SPV) cell

Maximum power point tracking(MPPT) Technique

When a SPV array directly connected to load the operating point of the SPV array will be meeting point of the load line I-V curve which is I-V relationship of the load is shown in the fig. 2.3. In other word we can say the impedance of the load indicate the operating point of SPV array. In general this operating point is seldom at the SPV array MPP. In most of the cases it will be different position thus it will not produce maximum power.

The solar photovoltaic (SPV) without MPPT, no index entries found, it cannot transfer the Maximum Power except one case when the SPV array internal impedance is equal to the load impedance. So a network to match impedance is required to make the load impedance equal to the source impedance. So by using the MPPT technique it make the load resistance equal to the source resistance by controlling the gate pulse of DC-DC converter. MPPT Technique is very essential part of solar photovoltaic (SPV) system. In fact there are so many method have been develop to track the maximum power point but the main issue is, which method is capable to find maximum power point at sudden changing environmental condition. In this system there are two MPPT Technique i.e. Perturb & Observe(P&O) and Incremental Conductance(INC) taken and discuss their performance for varying environmental condition

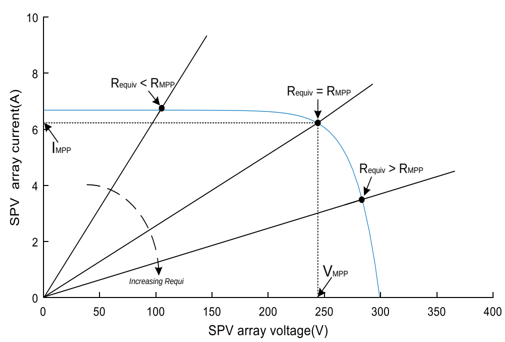


Fig.2.4: I-V curve of SPV array with different loads line curve

III. MODELING OF SOLAR PHOTOVOLTAIC (SPV) ARRAY

Basic mathematical equation of the Solar Photovoltaic cell is

$I_{PV} = I_{PH} - I_O[\exp\{\frac{q(Vpv+IpvRs)}{NsAkT}\} - 1] - (\frac{Vpv+IpvRs}{Rp})$ (2.1)

Where: I_{PV}=incident light generated current or photon current

I_O=reverse biased saturation current of diode

R_P & R_S=parallel and series resistance of the SPV cell

k = Boltzmann constant (1.3806503・10^−23J/K)

q = Charge of electron ($1.602*10^{-19}$C)

T = p-n junction temperature in (K)

A = Ideality factor of diode.

If the array is composed of N_p parallel connection of cells the photon and reverse bias saturation current may be expressed as $I_{ph}=N_p*I_{ph}$ & $I_o=N_p*I_o$ .The equation (2.1) describes the single model SPV cell. But for the practical use instead of I-V equation only need of data sheet.

IV. MECHANISM OF LOAD MATCHING

Consider the Buck-Boost converter is used between the SPV array and load . The Input- Output relation of the Buck-Boost converter is

$$\frac{Vo}{Vs} = -\frac{D}{(1-D)} \quad (2.2)$$

$$\frac{Io}{Is} = -\frac{(1-D)}{D} \quad (2.3)$$

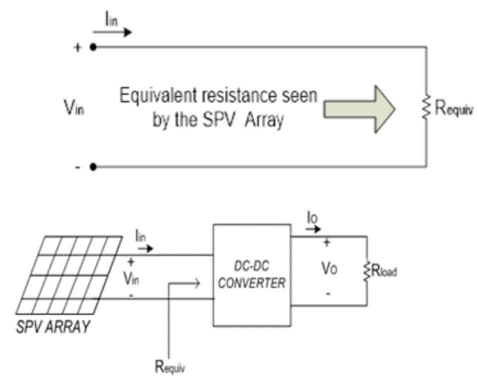


Fig.2.5: The equivalent circuit of MPPT system

V. SIMULATION RESULT OF SPV ARRAY-BUCK-BOOST CONVERTER FED VSI-BLDC MOTOR USING P&O MPPT TECHNIQUE

The very basic concept of Perturb& Observe (P&O) algorithm is, it gives the small perturbation in SPV array voltage (dV) and observe the change in SPV array power (dP), it will be the continue till, it reach the SPV array Maximum Power Point (MPP) shown in the fig (2.5).

P&O algorithm is very popular and because its simplicity, that is why it is easy to implementation most commonly used in practice. In this algorithm the SPV array voltage is varied by small magnitude (dV) and observe the respective change occurs in SPV array power (dP).

Perturbation	Change in power	Next perturbation
Positive	Positive	Positive
Positive	Negative	Negative
negative	Positive	Negative
negative	Negative	Positive

Table 2.6 : P&O technique Summary

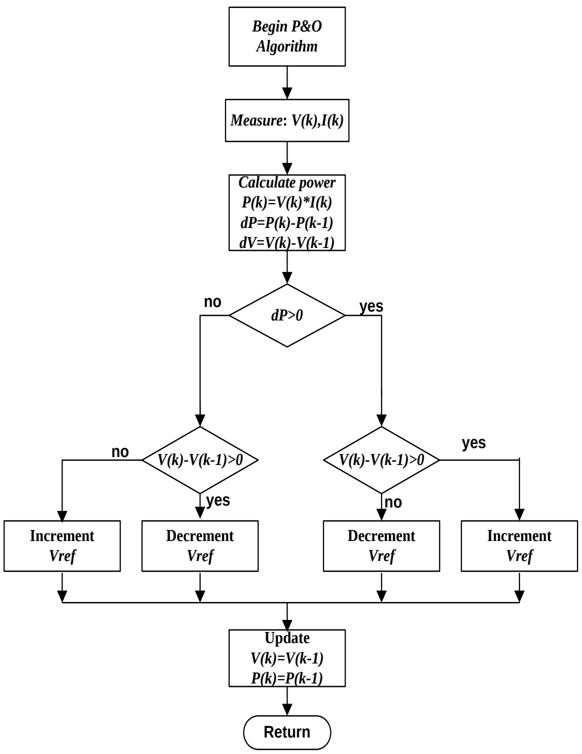


Fig.2.7: Flow chart of P&O algorithm

The flow chart of P&O algorithm is works as follow:-

i) Read *V(k)* and *I(k)* of SPV array

ii) Calculate *P(k)* by multiplying *V(k)* and *I(k)*.

iii) Call previous values of *P* and *V*, i.e. *P (k-1)* and *V(k-1)* from the memory.

iv) Calculate *dV* and *dP*, where, *dV* =*V(k) - V(k-1)* and *dP* =*P(k)- P(k-1)*.

v) Check the sign of (*dP*) and the sign of (*dV*) as follows:

- If (*dP*) greater than zero then immediately check the sign of (*dV*),
- if (*dV*) if greater than zero, then increment in array voltage, else, decrement .
- If (*dP*) less than zero pass then immediately check the sign of (*dV*),
- if (*dV*) if greater than zero, then decrement in array voltage, else, increment .

vi) Update the history, return for next iteration

A. (i) SPV array indices at constant irradiation (1000W/m²)

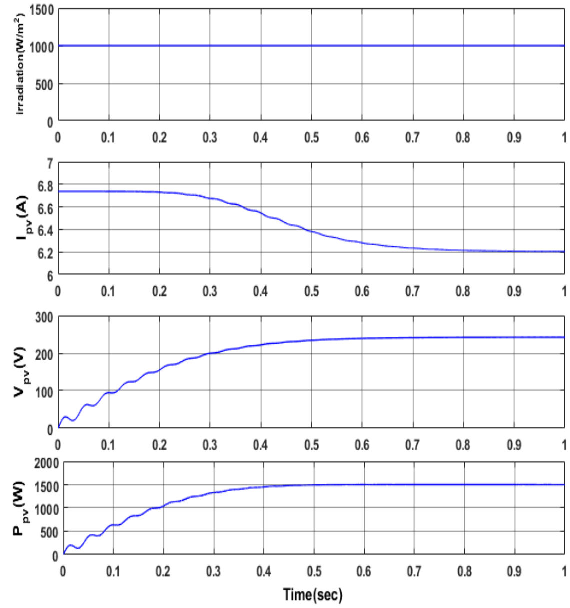


Fig.2.8: Performance of SPV array

(ii) Buck-Boost indices

V_{in} =241.5V, V_{out} = 300V, L = 3MH, C = 1205μF, f_{sw} = 10 kHz

1.	Open circuit voltage(V_{OC})	300V
2.	Short circuit current (I_{SC})	6.7A
3.	Voltage for maximum power point (V_{mpp})	241.5V
4.	Current for maximum power point (I_{mpp})	6.2 A
5.	Maximum power (Pmax)	1500W

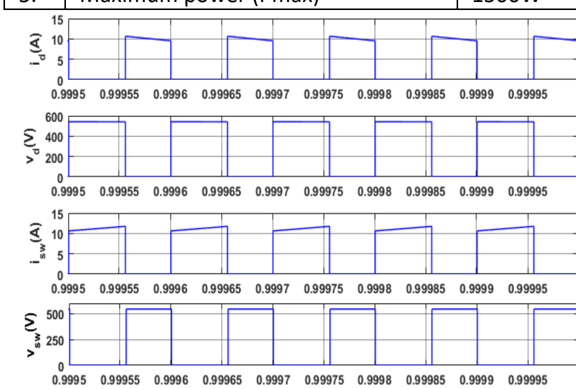


Fig.2.9: Buck-Boost converter performance

B. References

A Solar Photovoltaic cell is actually a semiconductor diode which p-n junction generates the energy [1]. There are many cells make the photovoltaic module and many modules which connected either series or parallel form the photovoltaic array further it is use for any type of load. Now it is obligatory to find that optimal point where the solar photovoltaic (SPV) cell can give possible maximum power with the use of a suitable MPPT technique.

There are many different techniques for finding maximum power points. In order to reliable cost, range of effectiveness and the hardware implementation complexity is to be simple, two MPPT technique Perturb and Observe (P&O) and incremental conductance (INC) selected in this work.

The MPPT technique adjust the duty cycle of DC-DC power converter which is an interface between voltage source inverter (VSI) and the solar photovoltaic (SPV) array supplying the power to BLDC motor. The buck-boost and Cuk [12-16] all these converters can work in any environmental condition as well as any kind of load because its operating range is full of quadrant of I-V characteristics of SPV array. The VSI is connected before the brushless DC motor which operated by means of electronic commutation for reducing the switching loss.

All implementation of project done in MATLAB Simulink software and result of Buck-Boost &Cuk with the P&O and INC are compared.

C. Abbreviations and Acronyms

MPPT,P&O, INC, SPV,VSI, FOCV,FSCC & BLDC.

D. Equations

$$I_{PV} = I_{PH} - I_O \left[\exp\left\{\frac{q(Vpv+IpvRs)}{NsAkT}\right\} -1\right] - \left(\frac{Vpv+IpvRs}{Rp}\right) \quad (2.1)$$

$$\frac{Vo}{Vs} = -\frac{D}{(1-D)} \quad (2.2)$$

$$\frac{Io}{Is} = -\frac{(1-D)}{D} \quad (2.3)$$

Let the converter is lossless, the relation of input - output voltage and current given in the equation (2.2) & (2.3) so the total equivalent impedance (*Requi*) seen by the SPV array

$$R_{equiv}\ (D,R_{load}) = \frac{V_{in}}{I_{in}} = \frac{V_S}{I_S} = \left(\frac{(1-D)^2}{D^2}\right) * R_{load} \quad (2.4)$$

From the equation (2.4) one thing is clear that the equivalent resistance is function of duty cycle as well as load resistance. By varying the duty cycle R_{equiv} can be matched the optimal resistance (R_{MPP}) to draw the maximum power from the solar photovoltaic (SPV) Array. Therefore, we can say impedance of the load mapped into the value that ensure maximum power transfer to the load.

VI. PUBLICATION RINCIPLES

Actually, in upcoming years the conventional source of energy will be nearly collapse. Thereafter the renewable source of energy especially solar energy will play very important role to fulfil the requirement of energy. Now a day the water pumping system even in industries, remote located agriculture field and household where there is no electricity supply using prominently.

So the best selection of MPPT technique, DC-DC converter and driven motor is very much needed. In this project there are comparisons of different types of DC-DC converter like Buck-Boost and Cuk has capability to work in any environmental condition for any types of loads with maintaining higher efficiency. The MPPT technique is capable to find maximum power point at sudden changing environmental condition.

It should have very less confusion around the maximum power point due to which very less oscillation around the maximum power point consequently power losses is very low.

The selection of motor is also very important task because weather dependent power source is in input side. The BLDC motor has noiseless operation, higher efficiency, electronic commutation and higher dynamic response. Due to trapezoidal back emf and rectangular phase current the BLDC motor gives comparatively lesser torque ripple.

The voltage source inverter (VSI) is used to feed the power to BLDC motor whose switch is controlled by hall sensor and electronic commutation.

- To design the solar photovoltaic cell in MATLAB Simulink software.
- To implement the perturb and observe (P&O) MPPT technique in MATLAB simulink.
- To implement the incremental conductance (INC) MPPT technique in MATLAB simulink.

- To implement the brushless DC (BLDC) motor with voltage source inverter (VSI) in MATLAB/ Simulink.
- To design the Buck-Boost and Cuk DC-DC converter in MATLAB/ Simulink.
- To implement the water pump with the BLDC motor

VII. CONCLUSION

In this project, the comparative study of two dc-dc converters i.e. buck boost & cuk converter is done and optimal operating performance by these two converters is discussed based on the simulation results. These converters are used in a PV system implemented with Perturb and Observe and Incremental conductance MPPT techniques. Both converters were designed based on the specifications given and Model is developed on the MATLAB/Simulink.

These models were implemented with the PV system, then the PV system along with converters is connected to BLDC motor through inverter. This BLDC motor drive fed by PV is useful in water pumping applications. The starting, dynamic and steady state behaviour of the overall water pumping system is verified with the help of simulation results. The system with cuk converter is better option compared to Buck- Boost converter.

The system efficiency is also compared for the two MPPT techniques i.e. Perturb and Observe and Incremental conductance along with cuk converter. The Incremental conductance provides better performance under rapidly varying environmental conditions. Hence, Incremental conductance with the Cuk converters is preferable and compatible combination for SPV based water pumping.

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