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CONVERGENCE OF MPPT ON MICROGRID CONNECTED PV SYSTEM

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Abstract: This paper shows the behaviour of of a microgrid which is fed by a PV source and the output of the grid which is controlled by a hysteresis controller . Maximum Power Point Tracking (MPPT) is used to track the maximum power, a Boost (dc to dc) converter is used to obtain the impedance matching between the PV array and the load. A solar inverter is used to convert DC input current to AC current . In order to track the maximum power Perturb & Observer algorithm is used.

Keywords: Microgrid, PV panel , hysteresis controller , MPPT, Perturb and Observe method , inverter

I. INTRODUCTION

The increasing demand for clean, reliable, and renewable energy is boosting research towards distributed generation (DG) systems like photovoltaic, fuel cells, wind turbines, and small hydro units . Many of these generators typically utilize the voltage-sourced inverter to interface with the grid and the load, as well as embedded control to improve power quality and protection .

This paper presents single-phase microgrid connected photovoltaic (PV) system that not only can inject active power to the grid but also can compensate harmonics and reactive power of nonlinear loads as a shunt active filter. It consists a control algorithm for a single-phase grid-connected photovoltaic system in which an inverter designed for grid-connected photovoltaic arrays can synchronize a sinusoidal current output with a voltage grid. The voltage output of microgrid should be verified and observed which is connected to PV generation as source . The output of PV model is enhanced by MPPT (P&O) method . A maximum power point tracking (MPPT) algorithm is used in order to obtain maximum power under different sun irradiance from PV; hence, in the darkness the system is used as an active filter and in the sunlight the system operates as both power conditioner and shunt active filter simultaneously. Boost converter is connected to PV source to step up the output signal of PV module . The PV systems are interfaced to the grid invariably by a power electronic inverter. Many of the important characteristics of the PV generation are influenced by the design and performance of the inverter, and hence suitable models of the inverter are needed to analyze PV systems. Several models of distributed generation (DG), including switching and average models, suitable for different study objectives . The grid-tied full bridge inverter conditions the power output of the photovoltaic array . The system's control mechanism is carried out by hysteresis controller which is fed to inverter . Circuit topology, conversion efficiency, maximum power point tracking, power quality, anti-islanding and cost are the main design considerations . Control of the presented system is based on Hysteresis control . Simulation results using MATLAB/SIMULINK verifies effectiveness of the system in injecting of maximum power captured by the PV system to the grid and compensating of the harmonic currents and reactive power of the nonlinear load.

II. MICROGRID PHOTOVOLTAIC SYSTEM AND ITS COMPONENTS

A. *Photovoltaic System*

PV module represents the fundamental power conversion unit of a PV generator system. The output characteristic of PV module depending on the irradiance intensity and the cell's temperature is nonlinear, so it is necessary to model it for the simulation of maximum power point tracking for stand-alone PV systems.

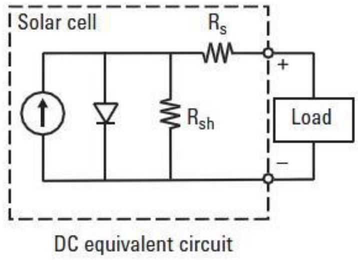

Fig i : Circuit diagram of a PV cell

A PV cell has a non-linear voltage-current (*V-I*) characteristic which can be modelled using current sources, diode(s) and resistors. Single-diode and double-diode models are widely used to simulate PV characteristics. The single-diode model emulates the PV characteristics fairly and accurate. For accurate modelling of the solar panel, two diode circuit could have been used.

B. MAXIMUM POWER POINT TRACKING TECHNIQUE

The PV systems connected directly to the load result in overall poor efficiency as such MPPT is to be introduced in PV systems to increase the efficiency of the system . Solar radiation, load impedance and module

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temperature are the three factors which affect the maximum power extraction from solar PV module. I-V curve of PV module is a function of irradiation and temperature which affects output current and voltage .The increased temperature decreases the open circuit. The efficiency of a PV plant is affected mainly by three factors: the efficiency of the PV panel (in commercial PV panels it is between 8-15%), the efficiency of the inverter (95-98 %) and the efficiency of the maximum power point tracking (MPPT) algorithm (which is over 98%) .

Perturb & Observe (P&O) is the simplest method. In this we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm.

The flowchart for the P&O algorithm is shown in Figure ii
In MPP operation, the PV-array produces maximum power under variable conditions of the solar irradiance and environmental temperature.

The maximum power point tracking (MPPT) algorithm that is used, is based on the differentiation of PV power and on condition of zero slope of PV curve.

$P = V \times I$ … (1)

Differencing the eq. (1) gives:

$dP/dV = dVI/dV$, …(2)

In condition of zero slope of PV curve where:

$dV/dP = 0$, we have:

$dI/dV = - I/V$ … (3)

When $dI / dV < - I / V$ the voltage must be reduced in order to achieve MPP operation. When $dI / dV > - I / V$ the voltage must be raised in order to achieve the maximum power point of the PV generation as shown in Fig ii .

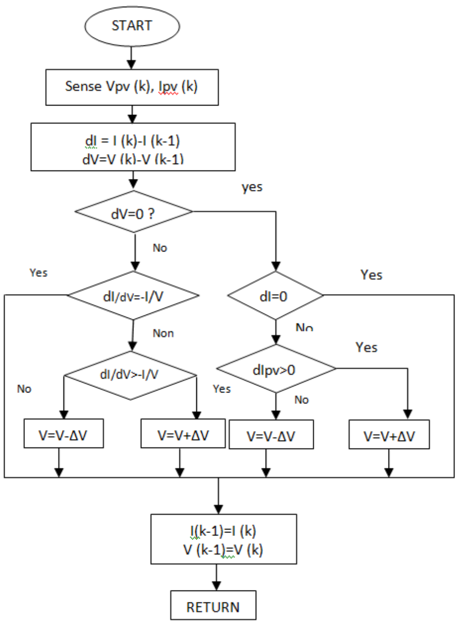

Fig ii : Flow chart of Perturb and Observe method

C. *Microgrid connected pv system*

A small grid connected to PV system is shown in fig iii .

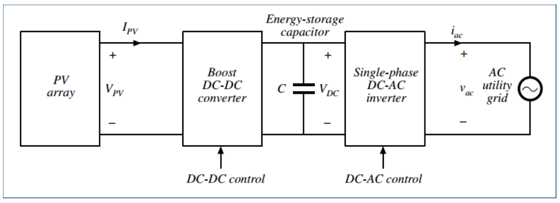

Fig iii : The simple diagram of a PV source connected grid system

For microgrid, there is an important difference with respect to large power systems, which is not only related to the size but also to the complexity of the logistics behind each action. The frequency of switching on and off micro-sources opens up the possibility of coordinating operation. Therefore there are usually many indispensable switches fixed on the different situation connecting distribution network with microgrid, microgrid with microgrid, microgrid with Loads, etc. For MG to work properly, the switch must have the ability to be on or off swiftly and autonomously when the scenarios require . The switch in MG needs consolidates the various power and switching functions such as power switching, protective relaying, measuring the voltage on both sides of the switch to allow synchronizing the island and the utility .

D. *Boost converter*

A boost converter (step-up converter) is a DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

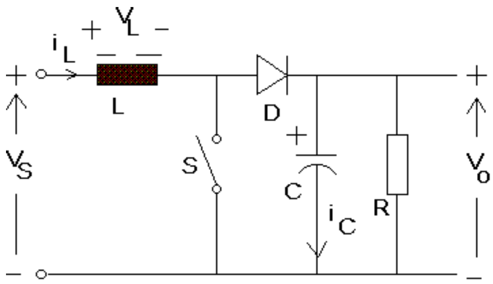

Fig iv : Boost converter circuit diagram

E. HYSTERESIS CONTROLLER

A Hysteresis control has two parts Voltage control mode and current control mode . Accordingly, the hysteresis control compares between the instantaneous value of a sinusoidal current reference and the inverter output current to generate the valve pulses . Assessing the impact of the inverter harmonic generation on the grid and optimizing its design requires an accurate representation of the inverter harmonic output .The hysteresis controller has a simple circuitry implementation, robust performance, fast dynamic response, and insensitivity to load parameter variation .

III. PV GENERATION SYSTEM AND ITS SIMULATION RESULTS

A. *Photovoltaic System Components and Modeling*

A single line diagram is studied in this paper and elaborated as diagrams as shown below . The microsources considered comprise a photovoltaic generator equipped with a Maximum Power Point Tracker (MPPT) and a Boost converter A battery is used as energy storage unit and is simply represented as a DC voltage source with adequate capacity, capable of meeting the real and reactive power commands within pre-specified limits .

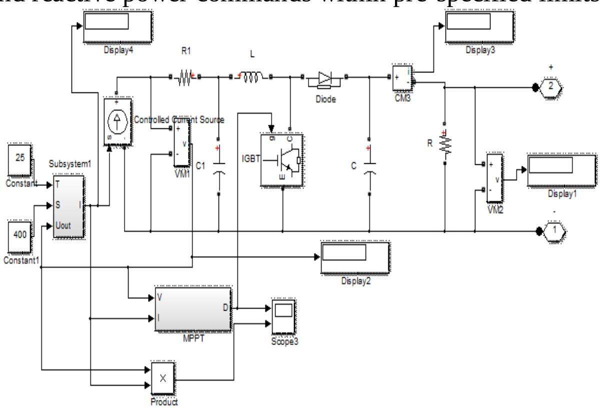

Fig v : MATLAB / Simulink diagram of PV system with Boost converter

As shown in fig.v a PV system has a PV module to which MPPT circuit is connected .There are two inputs given to PV module are temperature T and irradiation S . The output current and voltage of PV module are fed to MPPT . Then the duty cycle of MPPT is fed to IGBT which is used in Boost converter . The output voltage and current of PV module are supplied as input to Boost converter circuit . Then the voltage output of Boost converter is supplied to battery as output of PV source .

Temperature T= 25 ˚C
Irradiation S = 400
The output current of PV Ipv = 9.697 Amp
output voltage of PV Vpv = 74.93 Volt
The output current of PV system with converter Io = 1.693 Amp
and output voltage Vpv = 341.5 Volt

B. *PV module*

The Simulink model of PV module is shown in fig: vi .

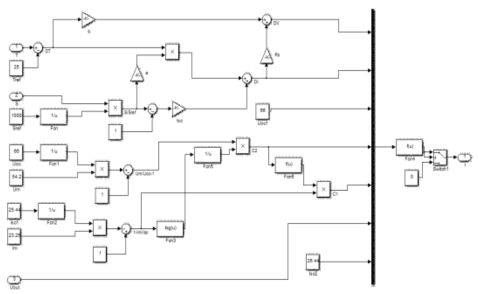

Fig vi : MATLAB/ Simulink model of PV module

In PV module ,
$Id = Io (e^{Vd/Vt} - 1)$
$Vpv = Vout - Rs\, Ipv$
Here Rs = 2.2 Ohm
Short circuit current Isc = 25.44 Amp
$Iph=[Isc + Ki(T\text{-}298)]*\lambda/1000$

$Ipv=Np*Iph - Np*Io[\exp\{(q*Vpv+Ipv*Rs)/NsAkT\}$

Vpv is output voltage of a PV module (V),
Ipv is output current of a PV module (A),
Tr is the reference temperature = 298 K,
T is the module operating temperature in Kelvin,
Iph is the light generated current in a PV module .
Io is the PV module saturation current (A),
A = B is an ideality factor = 1.6,
k is Boltzman constant = 1.3805 × 10-23 J/K,
q is Electron charge = 1.6 × 10-19 C,
Rs is the series resistance of a PV module,
Iscr is the PV module short-circuit current at 25 ^{o}C

TABLE 1
DATA FOR THE PV MODULE

PV Parameters	Value
Reference cell operating temperature (Tref)	25 ^{0}c
Reference Solar irradiance (Sref)	1000
Intial voltage (Uoc)	66 Volt
Module Voltage (Um)	54.2 Volt
Module Current (Im)	23.25 Amp
Short circuit current (Isc)	25.44 Amp

As shown in tables , these parameters are given to PV as per the equation,
P = V*I
The output of module is connected to a switch . Then the output current (I) and voltage (Uout)of PV module are supplied to MPPT circuit and Boost converter .
Uout = 74.93 Volt
I = 9.697 Amp
So P = 726.596 Watt

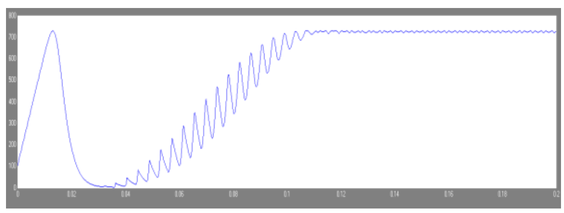

Fig vii : Simulation result of Power Vs Time Period of PV

C. *Boost Converter circuit description*

The output current and voltage are supplied to Boost converter . Boost converter step up the input voltage and the output of Boost converter is stored in the battery .
The Circuit diagram of Boost converter is shown in Fig : 4.1 . R1 is the input resistance to regulate the input current and C1 is the initial capacitor connected parallel to store energy . L is inductor to filter out the input signal from panel .
The circuit components and their values are elaborated as below .

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TABLE 2
DATAS FOR BOOST CONVERTER

Parameters	Values
R1	1 Ohm
C1	0.002 F
L	0.01 H
C	0.002 F
R	500 Ohm

The output voltage of boost converter V = 341.5 Volt output current of boost converter I = 1.693 Amp

IV. HYSTERESIS CONTROLLER AND ITS SIMULATION RESULTS

As hysteresis control is more efficient and effective than other controls , Hysteresis controller is connected between the inverter and grid . This achieves a substantial reduction in the magnitude and variation of the switching frequency, thus improving efficiency, while retaining all of the advantages identified with hysteresis current and voltage control. This Hysteresis controller controls the input voltage of the converter. The pulse width modulation is carried at a considerably faster switching frequency of 50 KHz. The controller works towards minimizing the error between Vref and the measured voltage by varying the duty cycle through the switch . The frequency spectrum generated by Sinusoidal (or Carrier) PWM inverters, is centred around frequencies that are integer multiples of the carrier frequency.

The circuit diagram of Hysteresis controller is shown in Fig: viii .

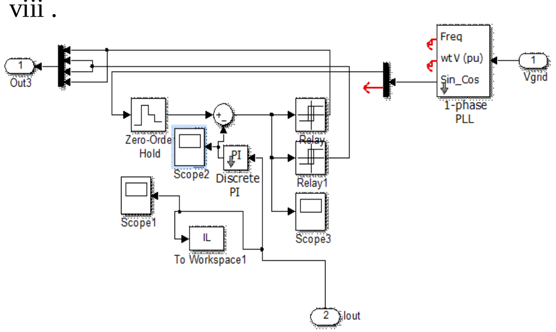

Fig viii : Hysteresis Controller Circuit

As per the above circuit Hysteresis controller has two inputs , current Iout from converter and Voltage Vgrid from Grid . Vgrid is fed to 1- phase PLL . Hysteresis bandwidth is a function of modulation frequency, supply voltage, dc capacitor voltage and slope of the reference compensator current waveform .In a hysteretic-controlled regulator, one important non ideal factor is the loop delay.

Simulation result of output of hysteresis controller after PI controller is shown in fig ix.

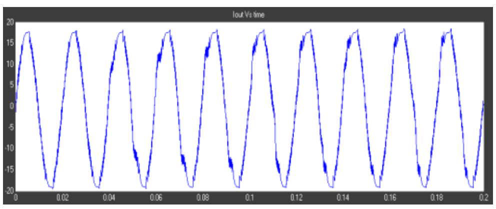

Fig ix : Simulation result of output of hysteresis controller

V. MICROGRID CONNECTED PV SYSTEM AND SIMULATIONS

Microgrid comprise low voltage distribution systems with distributed energy resources, such as photovoltaic power systems . These systems are interconnected to the medium voltage distribution network, but they can be also operated isolated from the main grid. The solar cell array produces only a small amount of current and voltage. So, in order to meet a large load demand, the solar cell array has to be connected into modules and the modules connected into arrays. The output voltage from PV array is changeable with solar radiation and ambient temperature. So in order to connect the electrical grid the output voltage from PV array should be fixed and converted to AC voltage which can be done by an inverter. The PV converter and inverter have the task to guarantee safe and efficient operation, to track the maximum power of the PV solar cell array and controlling the power which is injected from the inverters to the electrical grid . PV generation system is connected to a battery . The system consists of a DC-DC Boost Converter and a full-bridge inverter. The DC-DC Boost Converter implements a Maximum Power Point Tracker (MPPT) algorithm with regulated DC voltage while the full-bridge inverter implements a Hysteresis Current Control as the control method. These control method provides robust current and voltage regulation, achieve unity power factor, low THD and optimize the PV energy extraction suitable for grid connected PV systems.

As per circuit design here is a capacitor C connected parallel to PV source to give a continuous supply under any discontinuity and an inductor L is connected in series to filter out the source supplied signal . It acts as a DC source voltage .Installing a battery based storage system to reduce the power fluctuations of a large PV system .The battery acts as as a charge controller . As charge controller is used to power DC equipment with solar panels. The charge controller provides a regulated DC output and stores excess energy in a battery as well as monitoring the battery voltage to prevent under/over charging. So a battery is connected is connected parallel to PV source . More expensive units will also perform maximum power point tracking. An inverter can be connected to the output of a charge controller to drive AC loads. Then the supply is fed to bridge of Inverter . The inverter bridge receives gate pulse from Hysteresis controller . The inverter converts the variable DC output of solar panel into a utility frequency AC that can be fed into grid . The output of inverter is fed to microgrid . The structure allows a high power factor operation of a PV system, injecting a quasi-sinusoidal current into the grid, with virtually no displacement in relation to the line voltage at the point of common coupling among the PV system and the loads.

There are initial resistance Ri and Li . Li filtered out the AC voltage signal of inverter . There is a load R-L connected at output of microgrid . In the PV source the task of the MPPT algorithm is just to calculate the reference voltage Vm towards which the PV operating voltage should move next for obtaining maximum power output. This process is repeated periodically with a slower rate of around 1-10 samples per second. The external

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control loop is the Hysteresis controller, which controls the input voltage of the converter. Implementation of microgrid systems provide many advantages both from the user and from the electric utility provider. From the user's application of the microgrid is connected to the grid, it can improve network quality, reduce emissions and can reduce the cost to be incurred by the user. In the distributed PV generation, many circuit configurations of topologies can be observed, the Linear Circuit diagram of microgrid connected PV system with hysteresis control is shown in fig x .

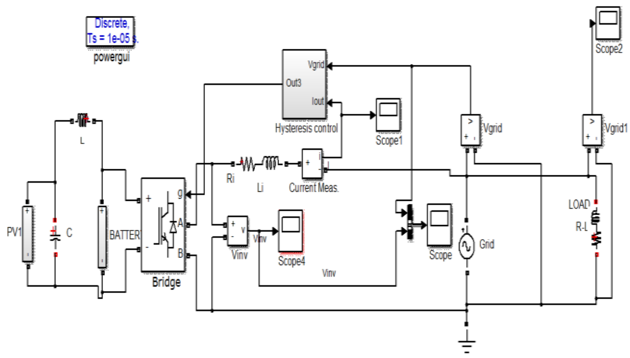

Fig x : Linear circuit diagram of microgrid connected PV system with hysteresis control

According to the circuit diagram as shown in fig: x the simulation result of the system is shown in fig xi .

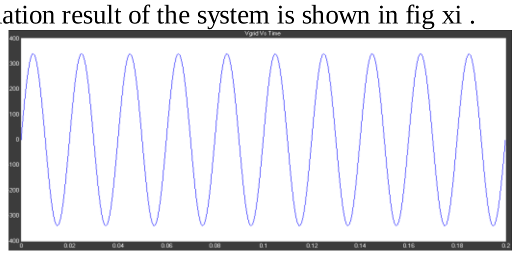

Fig xi : Simulation result of Microgrid with PV source

Fig. xi shows the output of the system through microgrid Voutput = Vgrid1= 341V .
As per model , peak voltage of Grid is Vpk = 240√2 Volt .

By verifying the THD of inverter bridge , the current signal and its FFT result is presented in fig: xii.

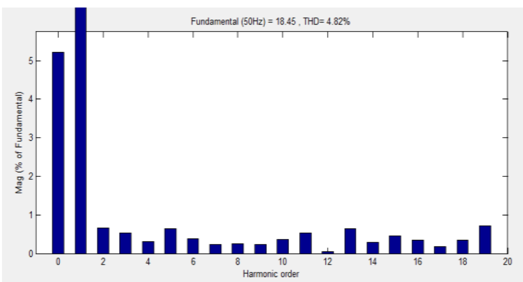

Fig xii : FFT Analysis of the system

VI. CONCLUSION

This is focused on analyzing the impact of PV installations representing high levels of penetration in relatively small load centres for a specified local area , industries, universities and also for isolated supply system during any islading condition . In order to construct a PV grid connected system, a number of parameters are taken into account and to be optimized in order to achieve maximum power generation. The maximum power point tracking algorithm when applied an accurate PV model has the ability to increase the efficiency of the system. In addition to that a Hysteresis controller is used in order to achieve the synchronization to the grid and to perform the power management between the system and the electrical grid. Hence the simulation of the Photovoltaic system with R load connected with Boost converter is conducted in MATLAB Simulink and verified . The inverter control system modelling is to be carried out in Matlab/Simulink 2010 environment. Moreover, this study shows that the proposed control scheme offers a simple way to study the performance for utility interface applications. It is simple to implement and capable of producing satisfactory sinusoidal current and voltage waveforms. To get better power quality, other control schemes for different inverter configurations and topologies are suggested.

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