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Implementation of Sustainable DC Grid Connected PV System during Day & Night

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Abstract: In this paper, a single-phase grid connected PV systems is proposed which provides constant power supply during day & night. This proposed system uses a transformer less conversion system, to provide an uninterruptable power a batter energy storage system is introduced. The power conversion system is controlled by a fuzzy logic controller implemented with MPPT technique. To eliminate harmonics and improve power quality kept a double tuned parallel resonant filter. A modified carrier based modulation technique for the current source inverter is proposed to inject current to the grid with a resonant controller. Simulation results are performed by using MATLAB/SIMULINK.

Key words:-MPPT, Fuzzy logic, double tuned filter, PV array, grid.

I. INTRODUCTION

Regrettably, the solar system remains idle until the mains power is restored to it’s property. Straightly grid connected solar PV systems are “the battery less”. The solar PV system requires a connection to an electricity supply to function properly. If there is no any grid supply available then solar PV system does not operate. The question is if a solar PV system produces energy whenever sun shines then why can't we use that produced energy even if the grid is not available. It has to remember that solar PV system is constant current source and therefore cannot increase or decrease amount of energy. it produces to handle a normal, appliances and home load demands.

If a solar PV system produces 8Amp then it cannot be produced more than that. Of course, Some appliances that operate at 8A or less could be run, but the fridges and appliances with the motors would not work as they require higher “surge” current to turn motor over. If you are suffering from frequent loss of power or that loss of power. Assuming that you are not already living off grid then you want to consider having battery backup system installed. Actually , if there are some appliances that you absolutely must run all time conditions, you have to definitely consider a battery backup system. You might have a water pump and computer equipment. There are mainly two types of battery backup systems for solar PV inverters DC coupled systems are better known as "off-grid" systems. Several solar panels are connected via a solar controller to the battery bank, to which a AC inverter is connected. These systems are having efficiencies of 92 to 94% as is opposed to the grid connect inverter efficiency of 95 to 97%. Batteries are either GEL or lithium-Ion, the latter are becoming more and more then popular. AC coupled systems, These is a general consideration if there is one or more number of renewable energy sources in a single system, such as combination of wind, hydro and photo voltaic systems. To connect all of these sources of power systems together and will be take an advantage of them during loss of grid supply is best done through AC coupling, thus it is taking advantage of the high-voltage energy sources of supply.

II. PV ARRAY MODELING

The building block PV arrays is the solar cell, which is a p-n junction that directly will converts light energy into electricity, it has an equivalent circuit as shown in Fig1.

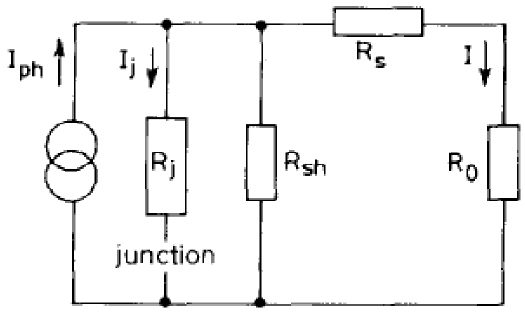

Fig1 Equivalent circuit of a PV cell

The current source(I_{ph}) represents a cell photo current; R_j parameter is used to represents a non-linear impedance of the p-n junction; R_{sh} and R_s are used to represents the intrinsic semiconductor series and shunt resistance of the cell respectively. Usually a value of R_{sh} is very much large and that of R_s is very very small, hence those are may be neglected to simplify analysis. PV cells may grouped in The larger units called solar modules which are further used to interconnect in series-parallel configuration to form a PV array or a PV generator. The PV mathematical models are used to simplify our PV arrays are represented by the equation.

$$I = n_p I_{ph} - n_p I_{rs}\left[\exp\left(\frac{q}{KTA} * \frac{v}{n_s}\right) - 1\right] \quad (1)$$

Where I is PV array output current; V is PV array output voltage; n_s is the number of cells in series and n_p is the number of cells in parallel; q is a charge of an electron; k is Boltzmann’s constant; A is p-n junction ideality factor;

T is cell temperature (K); I_{rs} is cell reverse saturation current. The factor A in equation will determines cell deviation from ideal PN junction characteristics; it is range between 1-5 but for the case A=2.46. solar panels are cannot be provide required power then extra comes straight from grid, if it is available. If you size one battery backup system and it is also too small to meet your load requirements then you may run of our power during a power cut.

The cell reverse saturation current ie., I_{rs} varies with temperature according the following equation

$$I_{rs} = I_{rr}\left[\frac{T}{T_r}\right]^3 \exp\left(\frac{qE_G}{KA}\left[\frac{1}{T_r}-\frac{1}{T}\right]\right) \quad (2)$$

Where T_r is cell reference temperature, I_{rr} is cell reverse saturation temperature at T_r and EG is band gap of the semiconductor used in cell. The temperature dependence of energy gap of semi conductor is given by:

$$E_G = E_G(0) - \frac{\alpha T^2}{T+\beta} \quad (3)$$

The photo current I_{ph} depends on solar radiation and cell temperature as follows:

$$I_{ph} = [I_{scr} + K_i(T - T_r)]\frac{s}{100} \quad (4)$$

where I_{scr} is cell short-circuit current at reference temperature and radiation, K_i is short circuit current temperature coefficient, and S is solar radiation in mW/cm2. The PV power can be calculated using equation as follows:

$$P=IV=n_p I_{ph} V\left[\left(\frac{q}{KTA} * \frac{V}{n_s}\right) - 1\right] \quad (5)$$

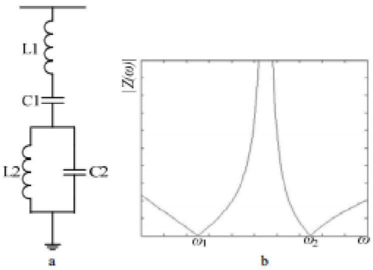

Fig2: (a)Double-tuned Filter Configuration and (b) Impendence -frequency Characteristic Curve

III. DOUBLE TUNED FILTER

The conventional double-tuned filter is composed of series resonance circuit and parallel resonance circuit. The structure and frequency impedance characteristic curve of traditional double-tuned filter are shown in Fig2. Series resonance circuit (L1、C1) and parallel resonance circuit (L2、C2) respectively have resonance frequency ω_S and ω_P. They can be expressed as:

$$L_1\omega_1 + \frac{1}{\omega_1 C_1} + Z_t = 0$$

$$L_1\omega_2 + \frac{1}{\omega_2 C_1} + Z_t = 0$$

$$\vdots$$

$$L_1\omega_n + \frac{1}{\omega_n C_1} + Z_t = 0 \quad (6)$$

$$C_1 = \frac{L_1C_2 - \frac{1}{\omega^2}}{\omega^2 L_1L_2C_2 - L_1 - L_2} \quad (7)$$

The impedance of double-tuned filter shown in Fig3 is:

$$C_1 = \frac{L_1C_2 - \frac{1}{\omega^2}}{\omega^2 L_1L_2C_2 - L_1 - L_2} \quad (8)$$

where ω is the angular frequency in radians. The impedance of series and parallel resonance circuit can be.

When $\omega<\omega_S$, the impedance is capacitive; when $\omega>\omega_S$, it is inductive. The impedance of parallel resonance circuit can be expressed as :

$$L_1\omega_1 + \frac{1}{\omega_1 C_1} + Z_t = 0 \quad (9)$$

$$L_1\omega_2 + \frac{1}{\omega_2 C_1} + Z_t = 0 \quad (10)$$

has a pole ω_P. When $\omega<\omega_P$, the impedance is inductive; when $\omega>\omega_P$, it is capacitive.

IV. MODIFIED CARRIER-BASED PULSEWIDTH MODULATION

Modified carrier-based pulse width modulation (CPWM) is proposed to control the switching pattern for the single-phase grid-connected CSI. In order to provide a continuous path for the dc-side current, at least one top switch in either arm and one bottom switch must be turned ON during every switching period. In conventional sinusoidal pulse width modulation (SPWM), the existence of overlap time as the power devices change states allows a continuous path for the dc current. However, the overlap time is insufficient to energize the dc-link inductor, which results in increased THD. Therefore, CPWM is proposed to provide sufficient short-circuit current after every active switching action. CPWM consists of two carrier waveforms, along with the switching pattern and one reference. The carrier with the solid straight line shown in Fig3 is responsible for the upper switches, while the dashed line carrier is responsible for the lower switches and is shifted by 180◦. To understand the switching patterns of the proposed CPWM, Fig3 is divided into ten regions ($t1 - t10$), and each region represents one carrier frequency period. Table I shows the switching combination for each of the ten regions. As shown in Fig3 and Table I, CPWM operates in two modes, a conductive mode and a null mode, and the switching action of each IGBT is equally distributed during every fundamental period. To validate the proposed CPWM, simulation results of a CSI operated by both CPWM and SPWM are shown in Fig6.

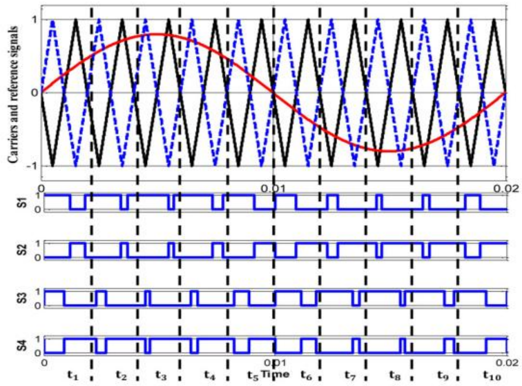

Fig.3 Sinusoidal pulse width modulation

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the shapes and fuzzy subset partitions of the membership function in both the inputs and output are shown in Fig4. A center of area algorithm (COA) is used in the defuzzification stage to convert the fuzzy subset duty cycle changes into real numbers [6].

TABLE II
FUZZY LOGIC RULES

	NB	NS	PS	PB
NB	PB	PB	NB	NB
NS	PS	PS	NS	NS
PS	NS	NS	PS	PS
PB	NB	NB	PB	PB

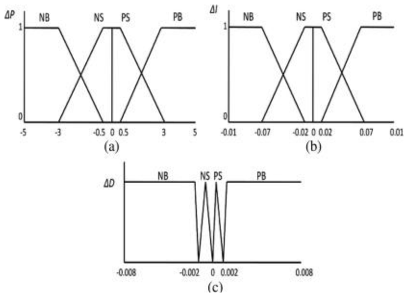


Fig4: Membership function: (a) inputΔP, (b) inputΔI, and (c) outputΔD.

$$\Delta I_{g.ref} = \frac{\sum_i^n \mu(i_{g.ref\ .i}) I_{g.ref\ .i}}{\sum_i^n \mu(I_{g.ref\ .i})} \quad (11)$$

where $\Delta I_{g,ref}$ is the fuzzy controller output and $I_{g,ref}$, i is the center of max–min composition at the output membership function. To ensure synchronization between the grid current and voltage, a sinusoidal signal generated by a phase-locked-loop (PLL) is multiplied by the MPPT output. Fig8 shows a block diagram of the MPPT structure. For precise control of the single-phase inverter, proportional resonant (PR) control is employed in the voltage and current loop controllers.

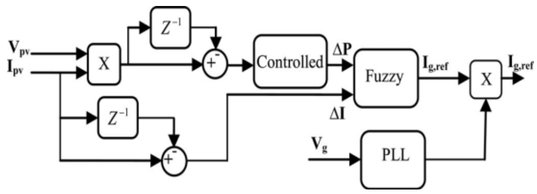


Fig5 Block diagram of the FLC-based MPPT.

The basic principle of the PR controller is to introduce an infinite gain at a selected resonant frequency in order to eliminate steady-state error at that frequency.

The PR controller transfer function is expressed as:

$$y = K_p e + K_i \frac{e_s}{s^2+\omega_0^2} \quad (12)$$

where K_p is the proportional gain, K_i is the integral gain, *e* is the signal error, and ω_0 is the fundamental angular frequency. The transfer function of the PR controller is digitized using the following derivation

Let

$$z(s) = K_i \frac{s}{s^2+\omega_0^2} e(s) \quad (13)$$

Rearrange (18) as

$$sz(s) + \frac{\omega_0^2}{s} z(s) = K_i e(s) \quad (14)$$

Let $w(s) = \frac{\omega_0^2}{s} z(s)$

By taking the derivative of (13) and (14) we have

$$\frac{dw(t)}{dt} = \omega_0^2 z(t)$$
$$\frac{dz(t)}{dt} = K_i e\text{-}w(t)$$

where *z* and *w* are auxiliary control variables used to facilitate the control design. In the following section, the subscripts *i* and *v* will be used with these control variables to signify the current and voltage controllers, respectively. the output of the PR controller can be rewritten as

$$y = k_p e(t) + z(t)$$

In order to compute the controller output) are solved numerically as

$$W(k+1) = W(k) + T_s \omega_0^2 Z(k)$$
$$Z(k+1) = Z(k) + T_s\big(K_i(k) - W(k+1)\big)$$
$$y(k+1) = K_p e(k) + Z(k+1)$$

VI. SIMULATION RESULTS

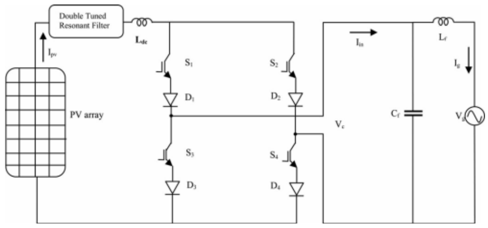


Fig6. Simulation circuit.

The proposed system is designed in MATLAB/SIMULINK software. PV array is modeled with solar cells. a double tuned filter is arranged to eliminated the dc harmonics in the systems. Current source inverter is placed with transformer less connection, integrated with grid.

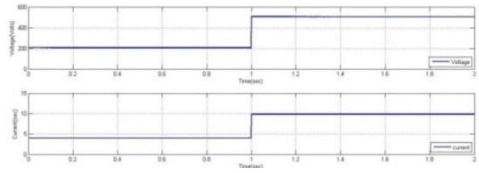
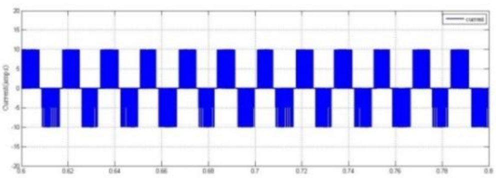
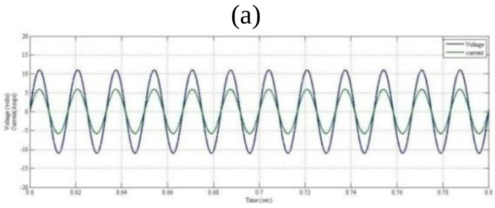


Fig7 solar panel performance during variation in solar irradiation.


(a)


(b)

In fig7 solar irradiation is varied suddenly at time 1sec 500 to 1000. The variation of soar irradiation will cause disturbances in the inverter grid system.

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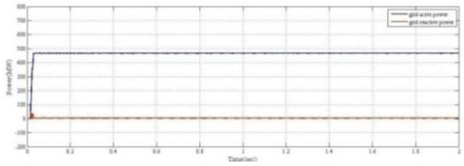
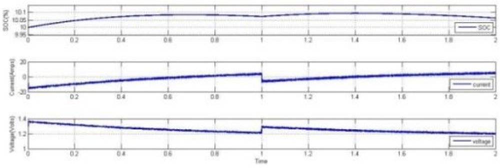


(c)



(d)

Fig8. variation in proposed inverter (a)inverter current (b)grid voltage and current (c)grid active & reactive power (d)battery storage characteristics.

To produce a continues power supply battery pack placed in the circuit, this battery will provide loss power to inject in the grid. Fig8(d) shows battery charging and discharging characteristics (SOC, current, voltage), fig8(a), (b), (c), (d) shows the waveforms of inverter current, grid voltage, current, active power, reactive powers.

V. CONCLUSSION

A single-stage single-phase grid-connected PV system using a CSI has been proposed that can produce a sustainable power supply to grid with low harmonic distortion. The control mechanism of the proposed system consists of battery control mechanism and a MPPT control technique to insert power supply in grid. Since the system consists of a single-stage, the PV power is delivered to the grid with high efficiency, low cost, and small footprint. A modified carrier-based modulation technique has been proposed to provide a lower harmonic distortion supply and to get maximum current. In this paper simulation is performed and analyzed results, proven that the conversion in the solar panel DC current to AC with purified power quality, in reasonable cost.

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