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Multiple Peak Tracking using Particle Swarm Optimization with Field Oriented Control for the Control of Induction Motor

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ABSTRACT: This paper deals with the design and simulation of a simple but efficient photovoltaic System with an improved maximum power point tracking (MPPT) method using a modified particle swarm optimization (PSO) algorithm and Induction motor is used as a load . The speed of Induction motor is control using a Field oriented control in addition to PSO based PV system. The main advantage of the method is the reduction of the steady state oscillation once the maximum power point (MPP) is located. .The PV array is modelled and its voltage-current characteristics and power-voltage characteristics are simulated and optimized. Furthermore, this method has the ability to track the MPP for the extreme environmental condition like large fluctuations of insolation and partial shading condition.

KEYWORDS: Buck–boost converter, DC-AC converter , max-imum power point tracking (MPPT), partial shading, particle swarm optimization (PSO), photovoltaic (PV) system. Field Oriented Control.

I. INTRODUCTION

The Conventional sources of energy are rapidly depleting. Moreover the cost of energy is rising and therefore photovoltaic system is a promising alternative. They are abundant, pollution free, distributed throughout the earth and recyclable. The hindrance factor is it's high installation cost and low conversion efficiency. Therefore our aim is to increase the efficiency and power output of the system. It is also required that constant voltage be supplied to the load irrespective of the variation in solar irradiance and temperature. To optimize the utilization of large arrays of PV modules, maximum power point tracker (MPPT) is normally employed in conjunction with the power converter. Most common MPPT techniques are Incremental conductance, Perturbation and Observation method (P&O), Hill Climbing method (HC).These technique produce oscillation during maximum power point tracking. In an effort to overcome aforementioned disadvantages, artificial intelligence approach such as fuzzy logic controller (FLC) and neural network (NN), evolutionary algorithm (EA) techniques, are used. Among the EA techniques, particle swarm optimization (PSO) is highly potential due to its simple structure, easy implementation, and fast computation capability , and to be very effective to deal with the MPPT problem. Induction motors are relatively rugged and inexpensive machines. Therefore much attention is given to their control for various applications with different control requirements. The most popular induction motor drive control method has been the field oriented control (FOC) Field oriented control is a vector control. The concept of field orientation control is used to accomplish a decoupled control of flux and torque.

II. MODELLING OF PV MODULE

Due to the low voltage generated in a PV cell (around 0.5V), several PV cells are connected in series (for high voltage) and in parallel (for high current) to form a PV module for desired output. Separate diodes may be needed to avoid reverse currents, in case of partial or total shading, and at night. The p-n junctions of mono-crystalline silicon cells may have adequate reverse current characteristics and these are not necessary. Reverse currents waste power and can also lead to overheating of shaded cells. Solar cells become less efficient at higher temperatures and installers try to provide good ventilation behind solar panels .The building block of PV arrays is the solar cell, which is basically a p-n junction that directly converts light energy into electricity: it has a equivalent circuit as shown below in Figure.2.

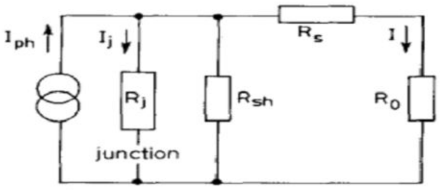


Fig .1. Equivalent circuit of PV cell

The current source Iph represents the cell photo current; Rj is used to represent the non-linear impedance of the p-n junction; Rsh and Rs are used to represent the intrinsic series and shunt resistance of the cell respectively. Usually the value of Rsh is very large and that of Rs is very small, hence they may be neglected to simplify the analysis. PV cells are grouped in larger units called PV modules which are further interconnected in series-parallel configuration to form PV arrays or PV generators. The PV mathematical model used to simplify our PV array is represented by the equation

$I=n_p\, I_{ph-}\, n_p I_{rs}\, [\exp(q/KTA * V/n_s)-1]$ (1)

where I is the PV array output current; V is the PV array output voltage; ns is the number of cells in series and np is the number of cells in parallel; q is the charge of an electron; k is the Boltzmann’s constant; A is the p-n junction idealist factor; T is the cell temperature (K); Irs is the cell reverse saturation current.
The cell reverse saturation current Irs varies with temperature according to the following equation:

$Irs=Irr[T/T_r]^3 \exp\,(\, q\, E_{G\,/}\, KA)\, [\, 1/\, T_{r\,-}\, 1/\, T]$ (2)

Where Tr is the cell reference temperature, Irr is the cell reverse saturation temperature at Tr and EG is the band gap of the semiconductor used in the cell.

The photo current Iph depends on the solar radiation and cell temperature as follows

$I_{ph} = [\, I_{scr} + K_i\, (\, T\text{-}Tr)]\, S/100$ (3)

where Iscr is the cell short-circuit current at reference temperature and radiation, Ki is the short circuit current temperature coefficient, and S is the solar radiation in mW/cm2.

PV ARRAY CHARACTERISTICS

The current to voltage characteristic of a solar array is non-linear, which makes it difficult to determine the MPP. The Figure below gives the characteristic I-V and P-V curve for fixed level of solar irradiation and temperature.

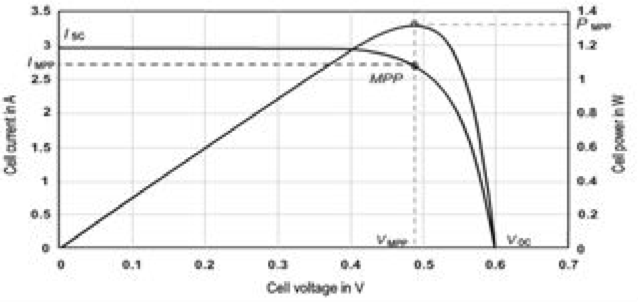


Fig .2. P-V, I-V curve of a solar cell at given temperature and solar irradiation

The characteristic I-V curve tells that there are two regions in the curve: one is the current source region and another is the voltage source region. In the voltage source region (in the right side of the curve), the internal impedance is low and in the current source region (in the left side of the curve),the impedance is high. Irradiance temperature plays an important role in predicting the I-V characteristic, and effects of both factors have to be considered while designing the PV system. Whereas the irradiance affects the output, temperature mainly affects the terminal voltage

III. MAXIMUM POWER POINT TRACKING CONTROLLER

The efficiency of a solar cell is very low. In order to increase the efficiency, methods are to be undertaken to match the source and load properly. One such method is the Maximum Power Point Tracking (MPPT). This is a technique used to obtain the maximum possible power from a varying source. In photovoltaic systems the I-V curve is non-linear, thereby making it difficult to be used to power a certain load. This is done by utilizing a boost converter whose duty cycle is varied by using a MPPT algorithm.

A. General Overview of PSO

PSO is a stochastic, population-based EA search method, modeled after the behavior of bird flocks. The PSO algorithm maintains a swarm of individuals (called particles), where each particle represents a candidate solution. Particles follow a simple behavior: emulate the success of neighboring particles and its own achieved successes. The position of a particle is, therefore, influenced by the best particle in a neighborhood Pbest as well as the best solution found by all the particles in the entire population Gbest . The particle position xi is adjusted using neighborhood Pbest as well as the best solution found by all the particles in the entire population Gbest . The particle position xi is adjusted using the following equation.

$$X_i^{k+1} = x_i^k + \phi_i^{k+1} \qquad (4)$$

It follows a simple behavior: emulate the success of neighboring particles and its own achieved successes. The position of a particle is, therefore, influenced by the best particle.

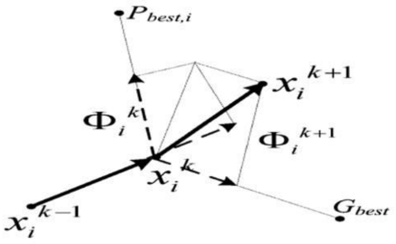


Fig.3. Movement of particles in the optimization process

where the velocity component Φi represents the step size. The velocity is calculated by

$$\phi_i^{k+1} = w\,\phi_i^k + c_1 r_1 \{ P_{besti} - x_i^k\} + c_2 r_2 \{G_{best} - x_i^k\} \qquad (5)$$

where w is the inertia weight, c1 and c2 are the acceleration coefficients, r1 , r2 ∈ U(0, 1), Pbesti is the personal best position of particle i, and Gbest is the best position of the particles in the entire population .It shows the typical movement of particles in the optimization process. If position is defined as the actual duty cycle while velocity shows the perturbation in the present duty cycle, can be rewritten as

$$d_i^{k+1} = d_i^k + \phi_i^{k+1} \qquad (6)$$

PSO, resulting perturbation in the present duty cycle depends on Pbesti and Gbest . If the present duty cycle is far from these two duty cycles, the resulting change in the duty cycle will also be large, and vice versa. Therefore, PSO can be thought of as an adaptive form of HC. In the latter, the perturbation in the duty cycle is always fixed but in PSO it varies according to the position of the particles. With proper choice of control parameters, a suitable MPPT controller using PSO can be easily designed.

B. Application of PSO for MPPT

To illustrate the application of the PSO algorithm in tracking the MPP using the direct control technique, first a solution vector of duty cycles with Np particles is determined,
The objective function is defined as

$$P(d_i^k) > P(d_i^{k-1}) \qquad (7)$$

To start the optimization process, the algorithm transmits three duty cycles di (i = 1, 2, 3) to the power converter. These duty cycles served as the Pbesti in the first iteration.
In the second iteration, the resulting velocity is only due to the Gbest term. This results in a zero velocity and accordingly the duty cycle is unchanged. . In the subsequent iteration, due to very low velocity, the value of the duty cycle is approaching a constant. Therefore, the operating point will be maintained and the oscillation around the MPP diminishes.
Change in duty cycle is calculated by following equation

$$d_{new} = d_{old} - 1/K1(P_{old,MPP} - P_{MPP}) \qquad (8)$$

where dold is the previous Gbest duty cycle and K1 = ΔPMPP/Δd is the slope of the linear segment

The value ofK1 is selected accordingly using the following relationship

$$K_1 = \begin{cases} K_1 & \text{if } \Delta P > 0 \\ K_1/2 & \text{if } \Delta P > 0 \end{cases}$$

Where $\Delta P = (P - P_{old})$ (9)

Note that ΔP > 0 and ΔP <0 indicate decreasing and increasing insolation, respectively. To perturb the new duty cycle is given below

$$d_i{}^k{}_{new} = [d_1 - K_{2,} d_2' d_3 + k_2] \text{ for } k_2 \geq 0.05. \qquad (10)$$

C. Control strategy of MPPT controller

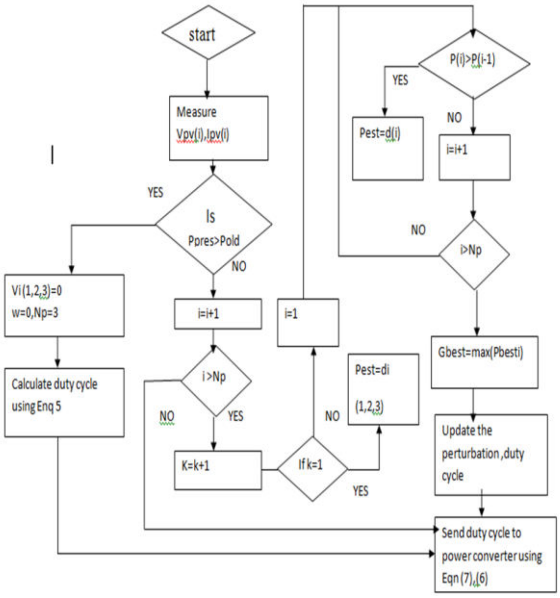


Fig .4. Flowchart of PSO based MPPT controller

IV. FIELD ORIENTED CONTROL FOR INDUCTION MOTOR

The most popular induction motor drive control method has been the field oriented control (FOC)
The recent trend in FOC is towards the use of sensor less techniques that avoid the use of speed sensor and flux sensor. The Field Orientated Control (FOC) consists of controlling the stator currents represented by a vector. This control is based on projections which transform a three-phase time and speed dependent system into a two co-ordinate (dand qco-ordinates) time invariant system. These projections lead to a structure similar to that of a DC machine control. Field orientated controlled machines need two constants as input references: the torque component (aligned with the qco-ordinate) and the flux component (aligned with d co-ordinate). As Field Orientated Control is simply

based on projections the control structure handles instantaneous electrical quantities. This makes the control accurate in every working operation (steady state and transient) and independent of the limited bandwidth mathematical model.

Transformation involved
- (a,b,c)=> (α,β) (the Clarke transformation) which outputs a two co-ordinate time variant system.
- (α,β)=>(d,q) (the Park transformation) which outputs a two co-ordinate time invariant system.

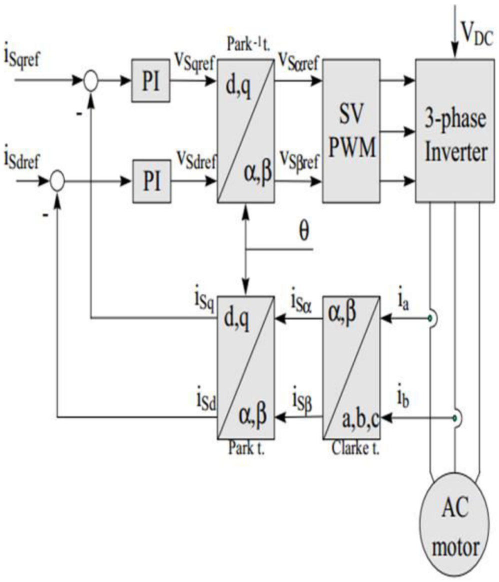


Fig.5. Basic scheme of FOC for AC-motor

V. PSO BASED PHOTO VOLTAIC SYSTEM

To collect maximum power from PV system, Particle Swarm Optimization(PSO) based maximum power tracking method is implemented.PSO is an Evolutionary Algorithm derived from Hill Climbing(HC) MPPT technique and Intelligence technique. Particle swarm optimization (PSO) is highly potential due to its simple structure, easy implementation, and fast computation capability Since PSO is based on search optimization, in principle, it should be able to locate the MPP for any type of P−V curve regardless of environmental variations. The main advantage of the method is the reduction of the steady state oscillation once the maximum power point (MPP) is located.

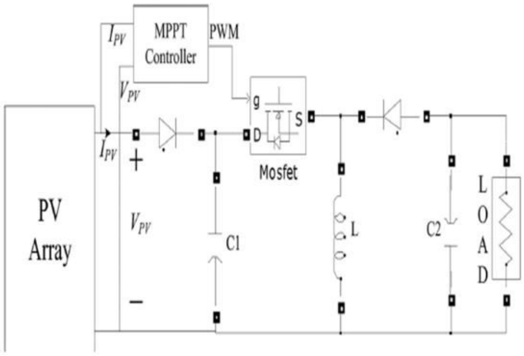


Fig.6.simulation model for the PV system with the buck–boost converter and MPPT controller.

Working is given below
- Simulate the PV array and measure Voltage and Current. From Voltage and Current, Power is calculated .This power is given to MPPT controller.
- MPPT controller worked based on PSO algorithm. Compared to other conventional MMPT techniques, it has faster tracking speed .MPPT Controller helps to take maximum power from PV array.

- The algorithm is implemented using a prototype DC-DC converter fed by a custom-designed solar array simulator. Converter regulate the power and given to load. Load used is a resistive load

SIMULATION DIAGRAM OF EXISTING SYSTEM

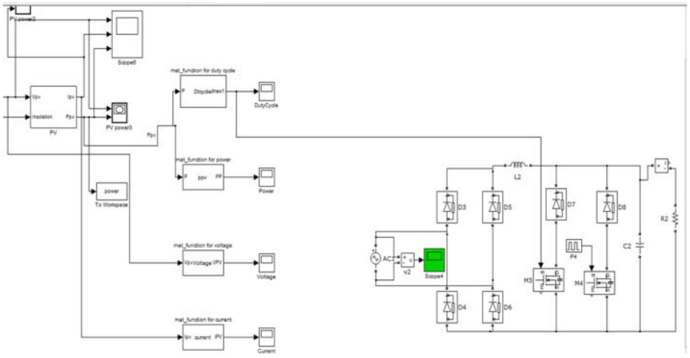
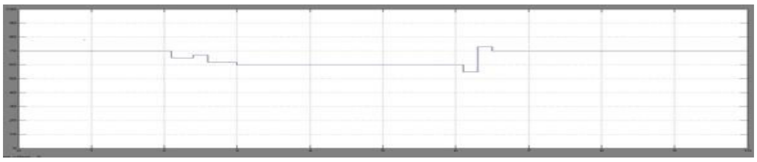


Figure.7. Overall simulation diagram with PV array and DC-DC converter

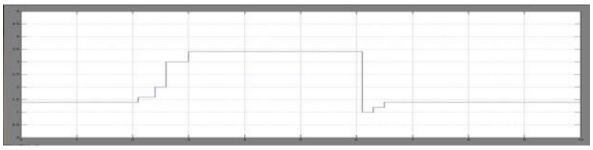
OUTPUT WAVEFORMS

Tracking duty cycle

Tracking Power



Tracking Voltage



Tracking Current

VI. PROPOSED SYSTEM

Present System concentrate on the implementation of Particle Swarm Optimization technique in PV system to collect maximum power from incident solar radiation. In proposed system instead of resistive load an Induction motor is connected to the existing system. Field Oriented Control is used to control the motor speed.

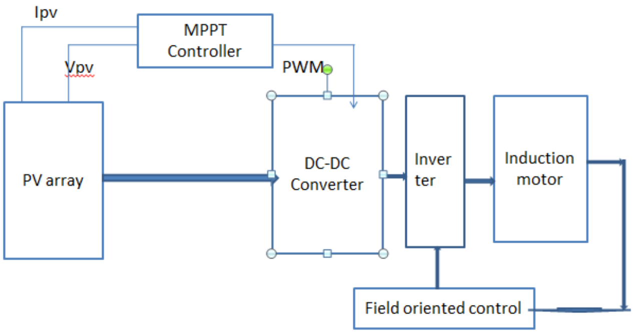


Fig.8. Block diagram of Proposed System.

System consist of PV array. MPPT Controller , DC-DC Converter ,field oriented controller, and Induction machine. Voltage, current generated from PV array is given to MPPT controller. Controller helps to track maximum power with the help of PSO algorithm. PWM signal generated from MPPT controller is given to DC-DC converter. DC output given to an inverter unit which convert DC to AC.
AC is given to Induction motor and its speed is controlled using field oriented controller

SIMULATION DIAGRAM OF PROPOSED SYSTEM

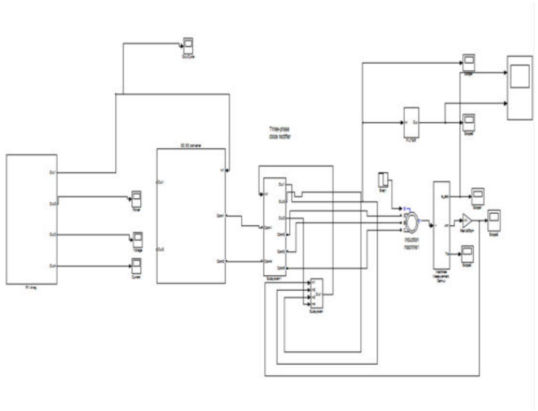
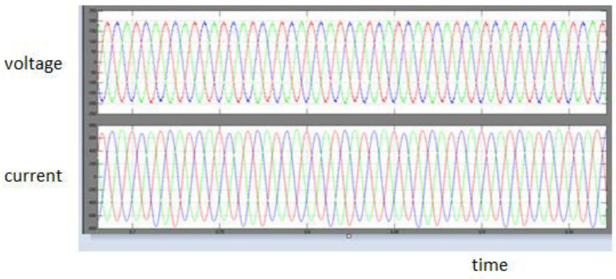
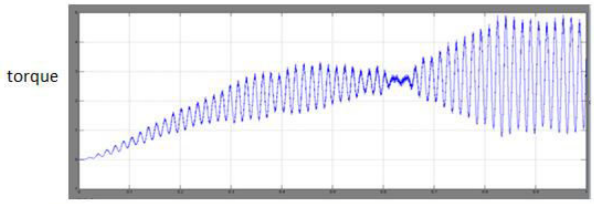
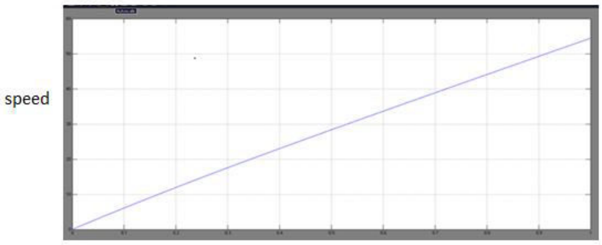


Fig .9. Simulation of proposed system

OUTPUT WAVEFORMS







VII. CONCLUSION

In this paper, a PSO with the capability of direct duty cycle is used to track the MPP of a PV system. The speed of Induction motor is control using a Field oriented control in addition to PSO based PV system. It is shown that the proposed MPPT controller exhibits an adaptive form of the HC method. To improve the tracking speed, a simple and efficient method is proposed to reinitialize the particles to search for the new MPP, resulting in superior dynamic response. The results indicate that the proposed controller outperforms the HC and gives a number of advantages: 1) it has a faster tracking speed; 2) it exhibits zero oscillations at the MPP; 3) it could locate the MPP for any environmental variations including partial shading condition and large fluctuations of insolation; and 4) the algorithm can be easily developed using a low-cost microcontrollers.

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