DESIGN AND PERFORMANCE ANALYSIS OF AUTOMATED TWO AXIS SOLAR TRACKING SYSTEM FOR PV MODULE

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Abstract

The project experiment proposes FPGA improve of a novel approach to track enlarge power point of solar photovoltaic array through automated two axis solar tracking system for PV Module and a novel approach to track the solar position as a sun detect direction and find a suitable position to attain enlarge energy in comparison with those in a fixed position as a sun array. In this process to approach uses Kalman Filter algorithm to track maximum power point, motor position and piston position. By using the proposal technique method, the MPPT can be tracked up to the efficiency of 94% within a time of about 4.8ms. The static position of PV array is tracked to an error of ±3% mostly. The experimental have been carried out in where partially shaded, falling the irradiance level of conditions. The proposed technique method is simple and cost effective in comparison to systems using GPS to track the position as a sun array direction.

Keywords: Solar Tracking System, Two Axis, Kalman Filter Algorithm, GPS.

Introduction

The solar radiation can be converted into electrical energy using Photovoltaic (PV) cells or solar cells which generate electrical energy by photovoltaic effect, i.e., building of voltage or direct electric current in a semi-conductor material when exposed to light. PV power generation is achieved using solar panels which are composed of a number of solar cells made up of a PV material (Shubhajit *et al.,* 2009). The entire Photo-voltaic array does not receive equal amount of radiations at all times. The output of a Photo-Voltaic panel is non-linear in nature as well as the output greatly varies with environmental changes like temperature, solar insulation, etc.

The PV array gives different output at different time of day for different orientations depending upon the amount of sunlight falling on the module and on the angle at which rays fall on it (Kalman, 1960). Thus the angle at which the module is placed with respect to the ground can be optimized so as to obtain maximum output from the module at all-times (Kranthi and Varun, 2012).

Review of Literature

Utilization of energy obtained from solar panel has been an important topic of research in recent times because of the growing requirement of sustainable resources of energy. The output of solar panel is very low hence optimization is required (Greg and Gary, 2006). This is achieved by using maximum power point tracking (MPPT) and adjusting of panels at an orientation which will yield maximum power output.

Trishan Esram and Patrick (2007) and Kang and Park (2011) made a comparison of a number of power point tracking techniques and worked on its efficiencies. (1960) described an effective computational (recursive) solution to the discrete-data linear filtering problem by estimating the state of a process that minimizes the mean squared error. These filters are extensively used in autonomous and assisted navigation by Greg and Gary (2006) indiscrete Kalman filters.

Research Methodology

To produce a larger voltage, a number pre wired cells in series all encased in tough weather resistant package to form a module. A single cell produces only a voltage of 0.5-0.6V and a few watts of power, hence it is of little use. When photo-voltaic are wired, they all carry same current and their voltages add. The PV module supplied to us contains 5 cells in series. We have 2 such panels, since the module is fabricated hence it is not possible to collect individual cell data. To overcome this we can use the given PV module and obtain the readings by shading all cells except cells of interest and collect data (Brahmaiah *et al.*, 2020).

Implementation of Kalman Filters in FPGA

Judging from the equations, we would need single precision adders, subtractions, multipliers and inverse. Since for solar PV array the quantities as all single matrices of orders 1X1

Construction of Basic Building Blocks:

Single Precision Float Adder:

Aim: To design a single precision float adder using VHDL

Equipment Required: Model sim 6.6d starter edition

Requirement: Two single precision float point numbers should be added, which meansinput width is 32 bits each and output width is 32 bits.

Inputs: clock=1 bit
Data a=32 bits
Data b=32 bits
Output: result=32bits
Observation: Data a=1
Data b=1
Result=2
Conclusion: The adder for single precision float numbers has been designed and simulated in model sim 6.6d and the test-bench waveforms recorded.

FPGA implementation of motor control

Stage-1: Finding difference between two voltages
Vm1= V3-V4

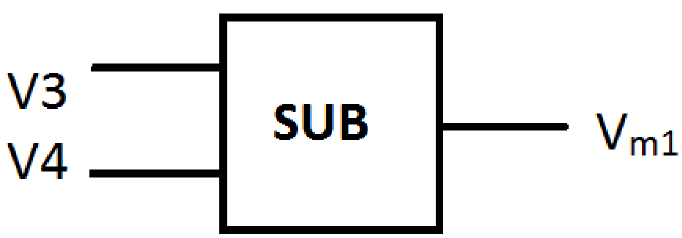


Fig. 01 Stage-1 of motor control

Stage-2: Finding the average of two voltages
Vm2= (V3+V4)/2 = (V3+V4)*0.5

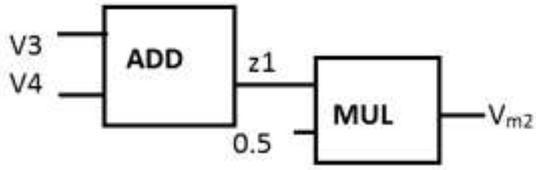


Fig. 02 Stage-2 of motor control

Stage-3: Finding U

U=Vm2-(V3-V4)

V3 or V4 is selected by using a 2:1 Multiplexer with Vm1 (31) as select line. When V3<V4, then Vm1 (31) =1 and V3 will be selected. When V3>V4, then Vm1 (31) =0 and V4 will be selected.

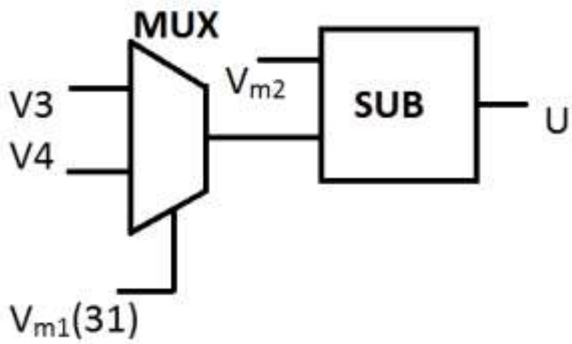


Fig. 03 Stage-3 of motor control

Stage-4: Rotation priori estimate at t Ө mt -= Ө mt-1±MU

Add sub block is used and its select line is again fed by Vm1 (31). When V3<V4, then Vm1 (31) =1 and V3 will be selected. When V3>V4, then Vm1 (31) =0 and V4 will be selected. Since our requirement is opposite of this, hence Vm1 (31) is negated before feeding it to the add sub block as select line.

Stage-5: Error covariance of priori estimate at t Zt -=Zt-1+Q

Stage-6: Kalman Gain at t

Kt = z- (zt-+R)-1

(Zt -+R) is found and its inverse is found because division is more complex.

Stage-7: Rotation posteriori estimate Ө mt = Ө mt ± Kt [Өreft-Ө mt -]

Add sub block is used and its select line is again fed by Vm1 (31). When V3<V4, then Vm1 (31) =1 and V3 will be selected. When V3>V4, then Vm1 (31) =0 and V4 will be selected. Since our requirement is opposite of this, hence Vm1 (31) is negated before feeding it to the add sub block as select line.

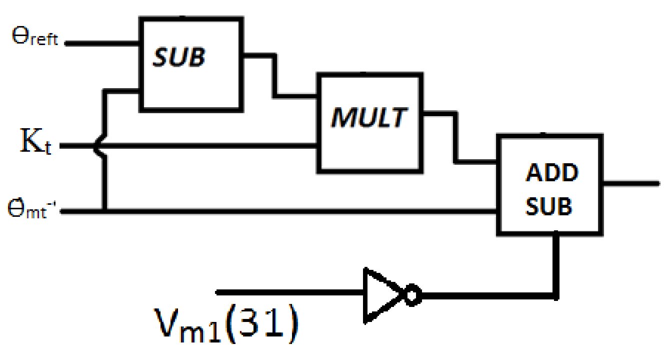


Fig. 04 Stage-7 of motor control

Stage-8: Posteriori error covariance estimate zt = zt –Kt Zt

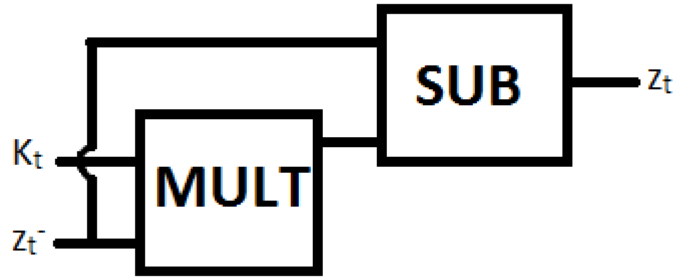


Fig. 05 Stage-8 of motor control

To design entire block model using structural model Equipment: Model sim 6.6d Altera starter edition and all components from Stage-1 through Stage-8 Input: clock=1 bit

V3 = 32bits

V4 = 32bits

ϴ mt-1 = 32bits

Zt-1 = 32bits

Output: ϴ mt = 32bits

Zt = 32bits

Intermediate signals required: *I*1-*I*14

Intermediate signals considered: *I*1, *I*3, *I*5, *I*7, *I*8, *I*9, *I*12

Intermediate constant signals: M, Q, R

*all intermediate signals are 32 bit wide

Signal mapping of intermediate signals

*I*1 = Vm1

*I*3 = Vm2

*I*5 = U

*I*7 = ϴ mt

*I*8 = ϴreft- ϴ mt

*I*9 = zt

*I*12 = Kt

Other signals are used internally.

Kalman Filters of Motor Algorithm

Let ϴ be the process and ϴt-1 be the known state measured variable is the high irradiance position at a particular time during the day.

Let it be ϴref

We have,

ϴt = ϴt-1 + MU

Here A =J and B =M

Rotation estimate priori at't' is,

ϴ t = ϴ t-1+MU … (1)

The process noise is assumed to be 0 initially Priori estimate of error covariance is

Zt = Zt-1 + Q …. (2)

Measured rotation is Ѳreft= Ѳ t + MU …. (3)

Here c=1

Equation (1) and (2) form prediction state The Kalman Gain is calculated from formulae

Kt = z - cT/ (cz - cT + R)

Since c = I in our requirement

Kt = Zt/ (zt + R)

K = z - (z + R)-1 …. (4)

Here A = J and B= M

Rotation estimate posteriori at‘t’ is,

Ѳ t = Ѳ t +Kt [Ѳreft- Ѳ t-] …. (5)

Equation (4), (5) and (6) form correction step

Control Element (MU)

From equation (1) in previous algorithm

Ѳ t= Ѳ t- 1+ MU

MU is dimensionless quantity in radians.

Sources in hand are two voltages V3 and V4

From control algorithm, control factor

U = Vm2 - (V3 - V4)

The unit of U is thus Volts (V)

The unit of M should be degrees/V

Ideal case: Let V3 has maximum and V4 has minimum measurable voltage on the panel

(Vmax - Vmin)V = 180

1V = 180/ (Vmax - Vmin)

Number of degrees/Volt = 1/(Vmax - Vmin)/180

Number of Volts = Vm2 - (V3 or V4)

Total length to be covered = (Number of degrees/Volt)*radius

Total control element is MU = Total length to be covered* Number of Volts/Radius in consideration

Dimensional Analysis: degree*l*V/(V*l) = degrees

Hence control element,

MU=180/(Vmax - Vmin)

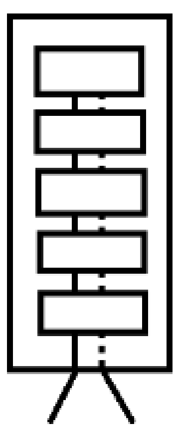


Fig.06: Solar Panel

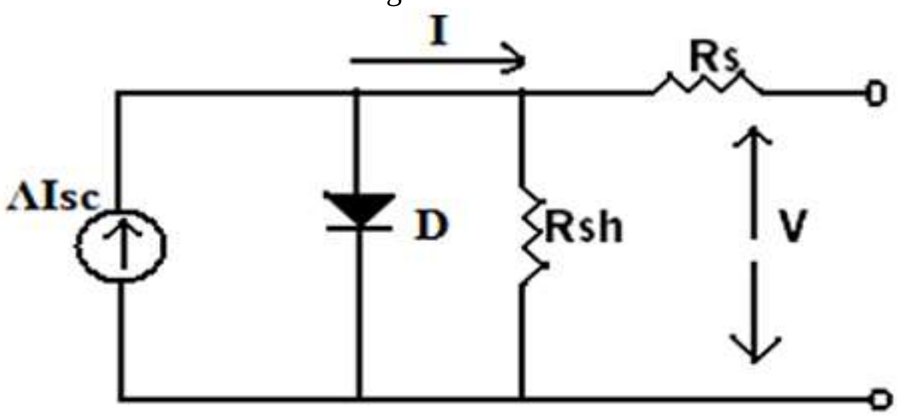


Fig.07: Solar cell equivalent circuit

We require a suitable mount which could support rotation of the module towards sun. This can be achieved by using a motor and solenoid powered cylinder. The piston length of cylinder will be calculated during the implementation for a rectangular module (Sharma *et al*., 2020).

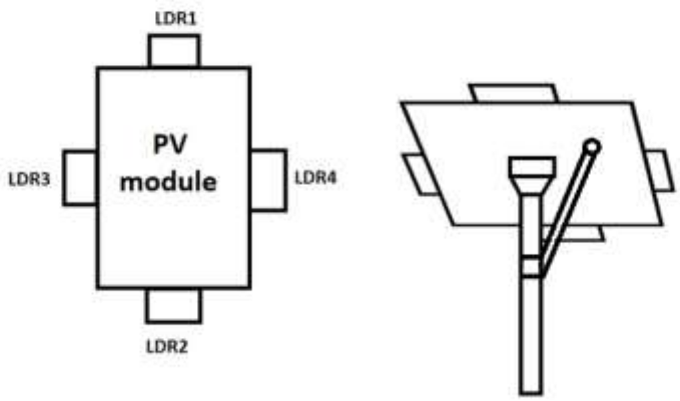
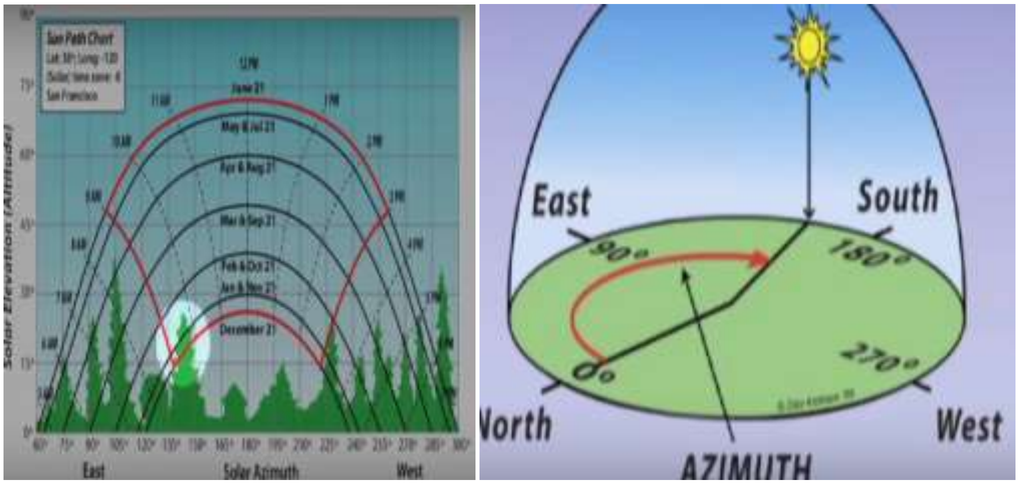


Fig.08: Design of mount (a) Top View (b) Rear View

From the figure 8, we can observe how the shaft is hinged to the module and how the solenoid powered cylinder piston head is attached to the module. The piston will be completely out in the noon hours and completely in the early hours of sunrise and sunset (Sharma *et al*., 2020).

For technical feasibility, we consider only 4 LDR circuitry in the module. The output of LDR3 and LDR4 is used for horizontal displacement and LDR1 and LDR2 is used for vertical displacement. Let V1 and V2 be voltages of LDR 1 and LDR2 and V3 and V4 be voltages of LDR3 and LDR4. (Figures 9 and 10).



(a) (b)

Fig.09: Solar elevation (Attitude)

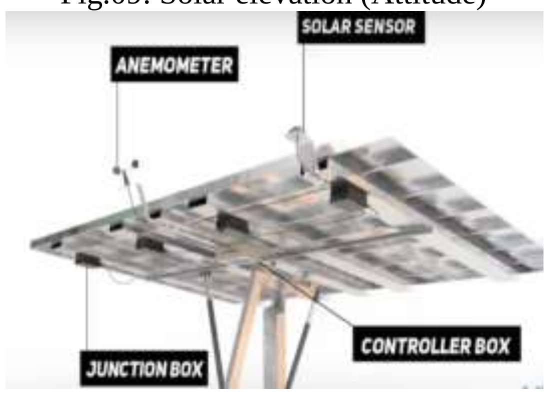


Fig. 10: Proto type of dual axis solar tracker

DISCUSSION

For implementation purpose, a 2.75V (open circuit voltage) and 2 mA (short circuit voltage) solar panel is used. It produces 5.5mW at 250c and 1KW/m2 irradiance. MPP varies from 1.7V to 2.75V depending upon environmental conditions. MPPT algorithm, motor algorithm and piston algorithm are implemented individually on cyclone-II, EP2C20F484C7 as implementation in reconfigurable architecture like FPGA ensured hardware based flexibility.

CONCLUSION

In this project, maximum power point tracking algorithm using Kalman filter has been proposed. Also, a dedicated algorithm for motor control tracking solar position using LDR sensors has been proposed including a dedicated algorithm for piston control tracking solar position using LDR sensors both based on Kalman filter. The maximum power point has been tracked with an efficiency of 94% and the combined system of motor and piston algorithm tracked solar position with an error of 3%. Further work can be done by interfacing motor and piston using the code written.

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