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Design and Interfacing of Variable Solar Panel Position Control System

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Abstract—*Hardware interfacing techniques and procedures of sensor less sun location based Solar Panel Position Control System using stepper motor through data port of personal computer is discussed. To calculate/ track the sun location based on day of a year and to direct the stepper motor to existing position of the sun, a virtual instrument (VI) software program using LabVIEW-integrated development environment (IDE) is designed and interfaced to the constructed hardware. The contribution of this paper is to present the feasibility of a high-performance Solar Panel Position Controller, which can be implemented by using a general purpose PC without any third party hardware etc to increase overall efficiency of the panel under different seasonal operating conditions.*
It is concluded by testing the hardware and VI design, by varying the position of the sun manually in PC. Solar panel position controller gradually approaches and stays in the direction of the sun. The benefit of this research work is it can be employed on a large scale in sustainable manner.

Keywords: *DC Stepper Motor Interfacing, LabVIEW VI, solar panel position control system*

1. INTRODUCTION

As we know, more solar radiated energy is received when solar panel is inclined towards the sun in a tangential position. In order to direct the solar cell in tangent with the sun or near to tangent position we face problems some of them related to sun and other related to solar cells. The problem related to the sun is that, the “deviation angle” which changes every day in the year as also known as true south, the deviation angle between -23.45 to 23.45 and the second is the elevation of the sun which is changes throughout the year, to be maximum elevation in summer and minimum in the winter as shown in Fig. 1, [1] the position of the sun on the plane of the earth is shown in Fig. 2 and is calculated by equation 1

$$\delta = 23.45 * \sin\left[\frac{360}{365} * (284 + n)\right] \qquad (1.1)$$

Where n is the number of the day in year

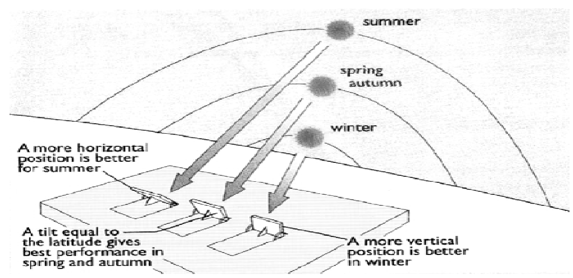

Fig. 1: Seasonal elevation of solar cell towards the sun

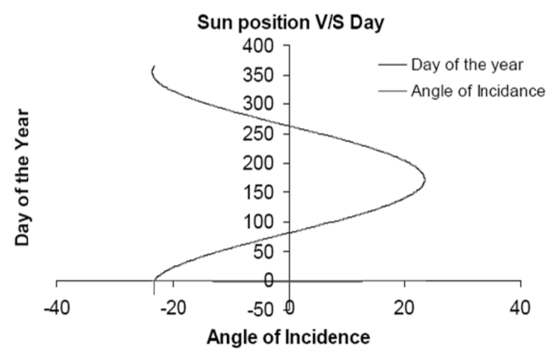

Fig. 2: position of the sun on earth plane

1.1 Tracking systems classification

The solar tracking can be done in many ways the following classification discussed here gives the idea of the position tracking of the sun

1.2 Rotating about east-west axis

In the case of tracking the sun continuously the panel rotating about east-west axis in the direction of north –south as shown in Fig. 3 (A) Then the minimum incidence angle will be

$$i = \cos^{-1}\left[1 - \cos^2 \delta \sin^2 \omega\right]^{\frac{1}{2}} \qquad (1.2)$$

1.3 Rotating about north-south axis

In the case of tracking the sun continuously the panel rotating about north-south axis in the direction of east-west this is required rotating every day to track the movement of the sun from sunrise to sun set as shown in Fig. 3 (B) then the minimum incidence angle will be

$$i = \cos^{-1}\left[\left(\sin\phi\sin\delta + \cos\phi\cos\delta\cos\phi\right)^2 + \cos^2\delta\sin^2\phi\right]^{\frac{1}{2}} \quad (1.3)$$

1.4. Rotating about vertical axis on horizontal plan

To increase the reception of solar energy the better axis for rotating is rotating about vertical axis and the lilt angle between a surface and the horizontal is equal to the latitude as shown in Fig. 3 (C) Then the incidence angle depend on declination angle

$$\left[i = \delta = 23.45\sin\left[\frac{360}{365}\left(284+n\right)\right]\right] \quad (1.4)$$

1.5. Rotating about two axis

In the case of tracking about two axis the incidence angle in this systems equal to zero during a day therefore getting the maximum beam radiation on surface and by using this type of tracking system getting approximately 38 % more than fixed systems

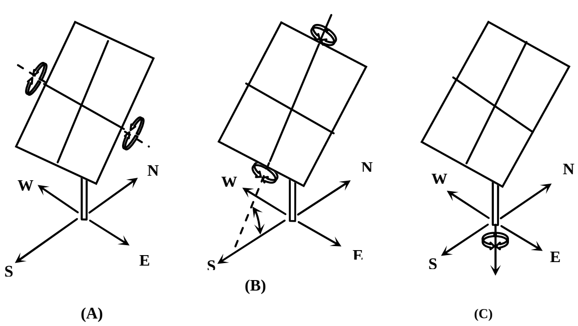

Fig. 3: Tracking types

Here third method is chosen, shown in Fig. 3.(C), which is Rotating about vertical axis on horizontal plan because of in our place (Arabic region) have intense sun radiation especially at noon and the movement will done by stepper motor and gear arrangement [2]. Here, this is purely a real time hardware implementation demonstration. The PC is used as a controller in the complete system in fact forming the open loop control system [3].

2. EARLIER TECHNIQUES

Different researchers have proposed many techniques, Wafa Batayneh et al, [4] carried out just simulation studies of the system with no real time implementation and they carried out using fuzzy logic controller technique. Nur Mohammad and Tarequl Karim [5] have presented two axis hybrid automatic solar tracking system using microcontroller. Manish Kumar Ghodki [6] presented solar power based electrical energy management system In order to improve the efficiency of solar module. Hong Yang [7] they have designed the Fresnel lens concentrated system and charging system M. A. Ozgur and G. Köse [8] studied, optimum solar panel positions determined for solar photovoltaic systems in Kütahya-Turkey, by testing different possible scenarios like; life cycle cost analyses were then performed and the systems were additionally examined both from technical and economic points of view. Guangyu Liu et al [9] they proposed a working mechanism of the physical design and mathematical modeling. A dexterous design, together with a gray-box modeling approach, that could measure the irradiation angle accurately

Some of the earlier techniques of stepper motor position controllers are shown in the Fig. 4 and in Fig. 5 which use below listed devices [10-11].

- PC with LabVIEW IDE
- PCI plugged in DAQ Board
- SCXI-housing Chassis
- Analog I/O Modules and Mount Terminal Boxes
- Driver Circuit
- Decoding Logic Circuit etc.(for simple stepper motor angular position control system)

Schematic of interfacing stepper motor to PC is shown in Fig.4. The motor is interfaced in the open loop control system configuration. The motor rotates in the forward direction i.e. in clockwise (CW) when +5V is applied from the system to the motor and the motor starts rotating in counter clockwise (CCW) when zero volts is applied from the system [10]. In order to perform this task a simple I/O VI is developed using LabVIEW Signal Conditioning Extension Instrumentation (SCXI), which is very expensive and non-efficient approach.

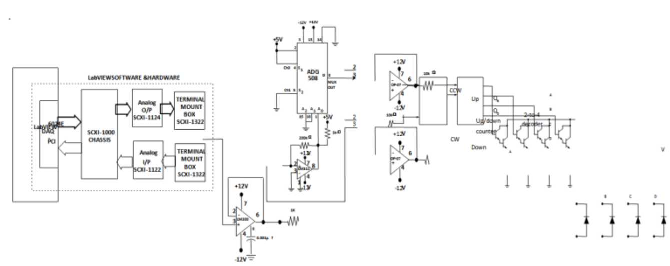

Fig. 4: Complete schematic of PC based stepper motor control through LabVIEW software

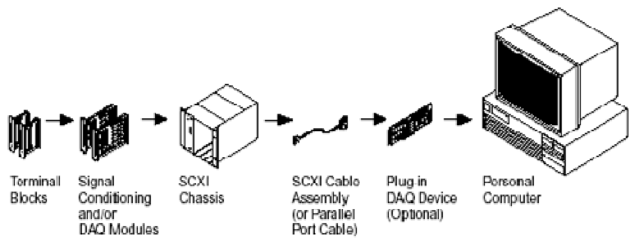

Fig. 5: Components of an SCXI System, DAQ board assembly used in order to access the analog signal or digital data from external world to PC and vice-versa

2.1 Motivation for the work

After literature survey, it is observed and concluded that, researchers [4-9] try to get solution for, "How to increase the exposure time of solar panel towards the sun and absorb more radiated sun light and increase the efficiency of solar panel" researcher [4, 6] uses sensors to direct the solar panel towards the sun to increase the absorption capacity of the solar panel, from study and analysis it is necessary to question "what happens if sensor fails to work properly due to sandy storms (like in Libya- Sahara/ other desert)", disadvantages with sensor based solar panel position controllers / directors is the maintenance/ every time cleaning of the sensors is required, any malfunctioning of the sensor could lead to whole system failure and need replacements and time to time checking and verification by technical expertise, which could be more expensive.

How if a system works free of maintenance or very less maintenance, in this article we proposed a system which works/ try to build a system to overcome the problem of less exposure time. Graph is drawn during a day in summer, to show the power efficiency of the static solar panel receiver as shown in fig.6 hours of the day versus power efficiency in wattage

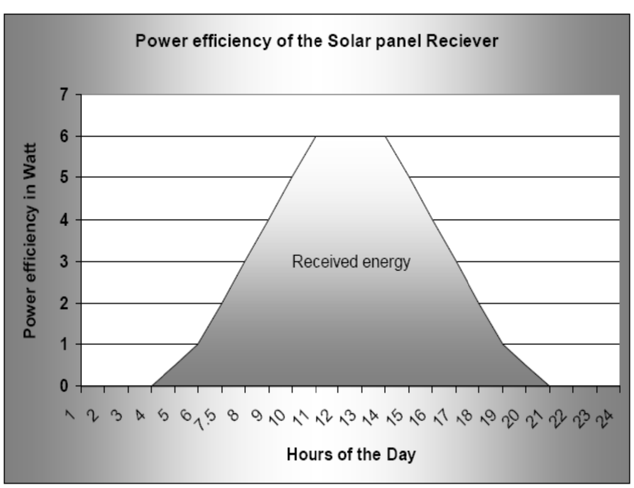

Fig. 6: Power efficiency of a solar panel receiver which is using static position control system

3. HARDWARE DETAILS OF THE SYSTEM

3.1 Block diagram of the system

Fig. 7 shows the block diagram of the system setup. Fig 8 shows the circuit diagram of the experimental system setup. It consists of personal computer installed with LabVIEW software to run VI, control signals are taken via data byte of Parallel Port (PP) D-25 pin connector, buffer, Driver/ actuator and finally applied to stepper motor, to drive the Solar Panel Position control system which is mounted on motor with the help of gear arrangements, forming simple open loop control system.

3.2 Working of the system

When a day in a year is entered in VI of PC, corresponding command signal for stepper motor will be generated and the control signal will flow through parallel ports 4-bits D0, D1, D2 and D3, of data byte to the buffer, Only four of its lines are used to drive next stage interface circuits board (breadboard), the buffered output command signals are visualized via light emitting diodes (LEDs which are connected to monitor the data flow from PC). Buffered output signal are feed to stepper motor, through the Darlington current amplifiers. The stepper motor drives the solar panel mounted on it.

Signal to the motor is maintained till the desired position is achieved and same position is maintained till next command for another day. This forms the simple open-loop control system for Solar Panel Position control system using DC Stepper motor. The schematic diagram is shown in Fig. 8 and photographs of the experimental setup are shown in Fig. 9(a) and in Fig. 9(b).

The analog voltages for sourcing the components are applied through the constructed power supply, using step down transformer, bridge rectifier, filter circuit, and regulator.

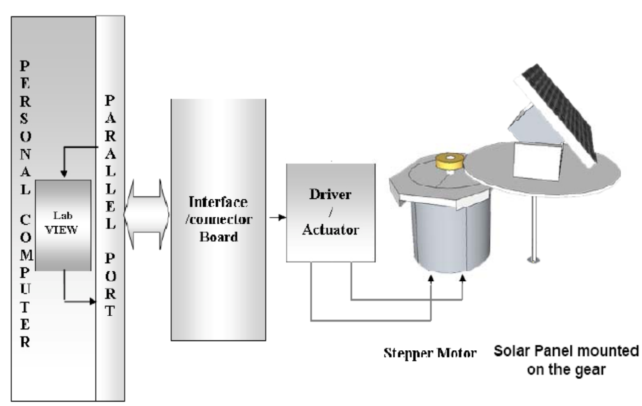

Fig. 7: Block diagram of proposed stepper Motor interfaced to PC and controlled with Virtual instrument (VI) created in LabVIEW IDE

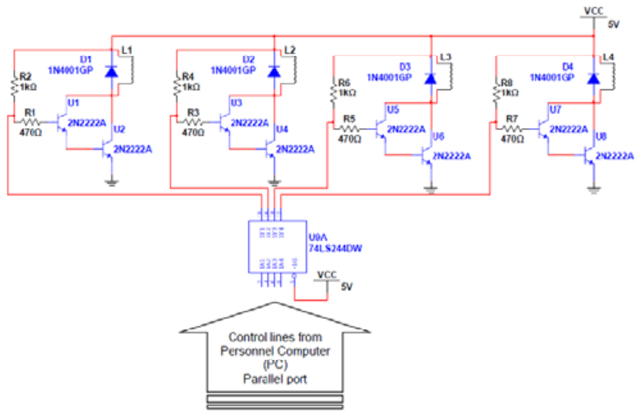

Fig. 8: Circuit diagram of the of the constructed experimental system setup

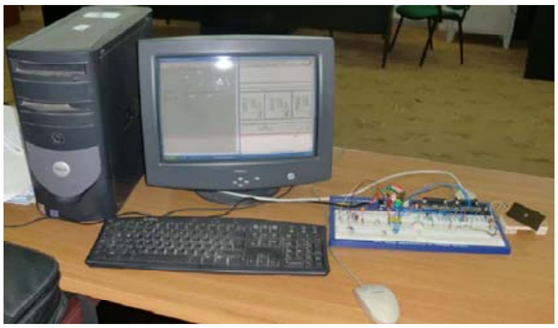

Fig. 9(a): Photograph of the experimental setup

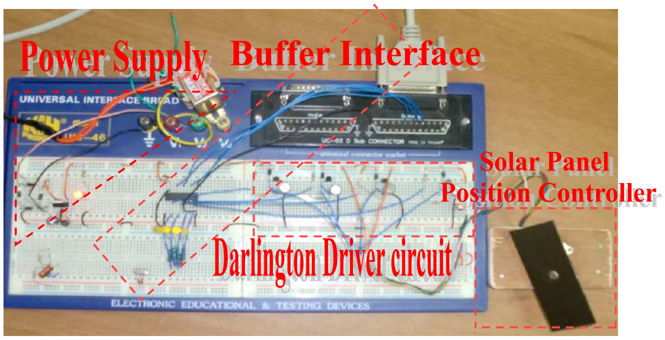

Fig. 9(b): Photograph of the experimental setup

4. EXPERIMENTAL IMPLEMENTATION

Simple ON/OFF control technique is implemented. When a day of the year is entered corresponding voltage in D0-D3 are generated in (in hexadecimal 03H, 09H, 0CH and 06H). Using Equation 1

4.1 Virtual instrumentation Software Details

The VI software is used to apply and change the voltage to the Motor with respect to the real time needs of the user and rotate the motor for required direction as per the day, this is done by the VI. It imitates the appearance and operation of any other physical instrument. VI is defined as a process of combining hardware and software with industry standard computer technology to create a user-defined instrumentation solution. Because their appearance and operation imitate physical instruments, such as switch, LED, oscilloscope, multi-meter etc [12].

4.2 LabVIEW

As everyone knows LabVIEW Graphical User Interface (GUI) IDE uses terminology, icons, and ideas familiar to technicians, scientists and engineers. LabVIEW programs are called virtual instruments Each VI consists of two main parts:

a. Front panel or Front end diagram (user interface) and
b. Block diagram [12] (where functional source coding is done, using equations, flow logics and etc)

4.3 Design of front panel

The front panel VI reads the day(to be applied to the motor via the front-end hardware user interface) entered by the user and sets the voltage sequences in data nibble through PCs parallel port and controls the motor voltage as per the front panel VI command menu. The control function forms the programming part as per the user requirement and the hardware will be the same for any type of control function. Fig. 10 shows the front panel diagram which contains forward/ reverse switch, knob dialer menu to enter the day of a year in a particular location, time delay for data output speed, output port if multiple parallel ports are used etc[12].

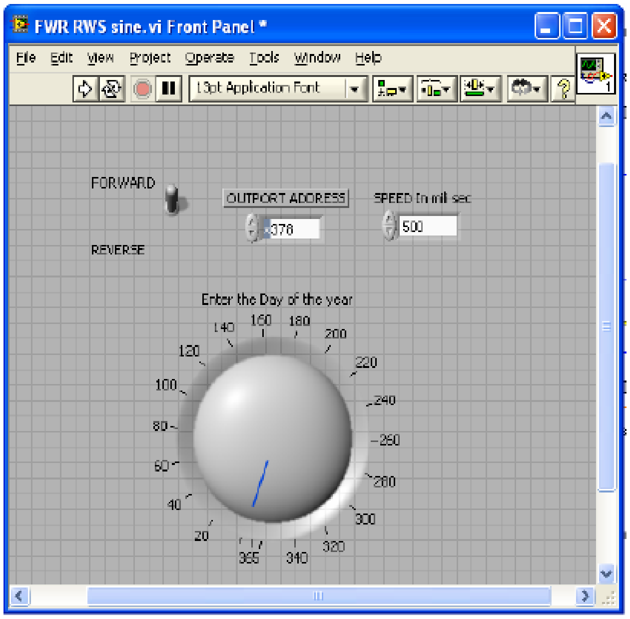

Fig. 10: Front panel diagram user interface VI diagram

4.4 Block diagram (source code) designing

The block diagram or the source code involves for-loop, while-loop and sequence nested structures, Boolean-control-bit which represents binary digit, array builder, binary to 32-bit digit converter and other icons, which are self explanatory. The function diagrams or the source code diagram is shown in in Fig. 11.

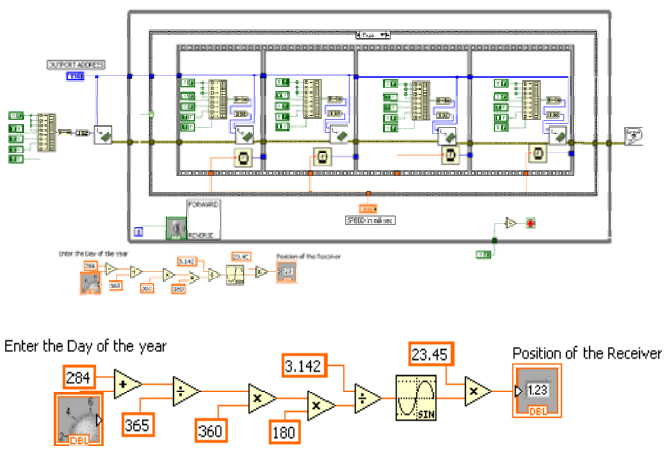

Fig. 11: Block diagram or source code of VI diagram for ON-state and applying different control voltages to the out port

The mathematical expression for the position controller which is used in our work is given in equation 1

In which, 'n' is the number of the day of the year When someone enters the number of the day from Day-1 to Day-365 from the year, any one number at n and substitutes in the above equation for the position angle control of solar panel receiver, for that particular day in 365 days is displayed in-terms of the degrees. It is shown in Fig. 11.

D0-D3 is, 'Digit indication of hardware LED. (Magnitude applied to the motor). If LED is ON 'rated-high' voltage magnitude is applied to the motor. If LED is OFF 'rated-low' voltage magnitude is applied to the motor. D0 is the LSB and D3 is MSB. The rated proportional voltage is applied in sequence of hexadecimal values, as shown in table 1.

Table 1

MSB D3	D2	D1	LSB D0	Hexadecimal value applied to the motor
0	0	1	1	03H
1	0	0	1	09H
1	1	0	0	0CH
0	1	1	0	06H

When a day is entered corresponding digit/s enabled with Low or High voltage magnitude levels from Digit-1 to Digit-4, the corresponding TRUE/ FALSE bit is enabled in the block diagram. Since, the true or false bit is single bit, it is connected to the Boolean array builder which is used to build 8-bit array. Then the 8-bit array is converted in to 32-bit number and the 32-bit number is converted into 32-bit integer. The 32-bit integer is applied to the out-port-byte through-which, finally, the command word exits out of the PCs parallel port to the motor. State of the motor depends upon the control word. The combination of the digits gives different equivalent voltages. Table 1 gives the magnitudes of the applied voltages to the motor. The result is, change in position proportional to the applied voltage. In-turn it is command word generated from the front panel user interface. The VI provides on-line variation of day or set point, which facilitates the system to study for different variations. The behavior of motor on adding/ subtracting different magnitudes can be monitored.

A complete VI is developed using the icons, in block diagram for proper functioning of motor control is shown in Fig. 11.

5. EXPERIMENTAL OBSERVATIONS

The experimental studies are carried out to verify the feasibility of the VI for different conditions. The experiments are carried to test the performance of the VI and circuit constructed, by entering every alternate day from day 1 to day 365 in VI and it is noticed that, the solar panel could be exposed to more sun light in turn resulting higher efficiency of the Solar Panel.

5.1 Comparisons of conventional DAQ based motor controllers and our interfaced circuit

Fig. 12 shows the comparisons of the conventional/ static solar panel receiver and system constructed by author from the graph it is very clear that, by using our system the solar panel is exposed to sun light for more time.

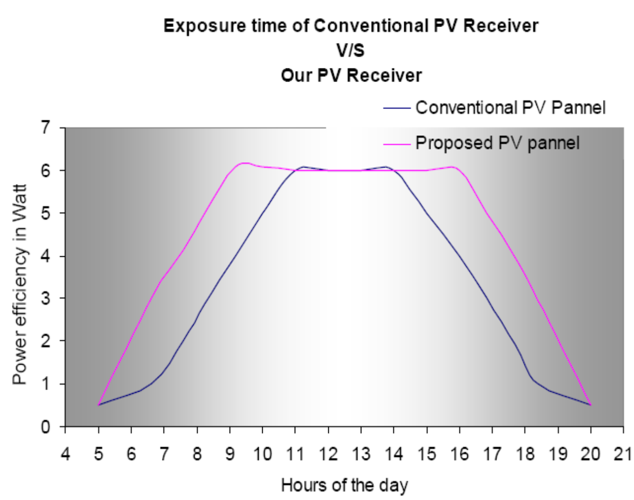

Fig. 12: Comparison of the results of the conventional system and our designed system

Rotating the motor as a sunflower, the solar panel is able to receive more sun light and in turn the average power generations will increases. One more advantage of our system is it is sensor less and is well suited for resisting the sand storms especially in countries like Libya/ desert.

6. CONCLUSIONS

The designed and developed system is first in its own kind, i.e. without using any commercially available DAQ or interfaces like PCI/ SCXI/PXI/USB based boards. (In order to control any physical parameter, investments in vendor software and hardware are must. From small to large scale applications data from external world to the PC can be transmitted). It is non-expensive LabVIEW based Parallel Port Data Acquisition System for analysis and experimentation. The dedicated system using large scale solar cells can be designed and constructed using our system. This would be a cost effective solution and a great exercise for the new bees.

6.1 Future Scope

There is a scope for further development of this system. In future, VI application might require fewer changes in code or even someone may consider developing a totally new closed-loop data acquisition package using hybrid or multi dimensional control system using many hardware motors and control VI softwares Since the output is different voltage level control, different PMDC motors may be used and their behavior can be studied, for irregular to abrupt change conditions. Potential divider technique may be employed for direct position variation implementation in VI

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