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MODELLING AND SIMULATION OF MAXIMUM POWER POINT TRACKING TECHNIQUE FOR SOLAR WATER PUMPING SYSTEM

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ABSTRACT
Renewable energy technologies are playing significant role to providing the world's electricity demands and supplies. The photovoltaic generation system is the most promising energy source for the future, is growing fast and exhibiting an industrials development worldwide. Solar energy which is ultimate and available in most areas of the world has proven to be cheap source of energy in various applications. The earth receives energy from the sun is so massive and so lasting that the entire energy consumed yearly by the whole world is supplied in as short a time as approximately half hour. The sun is a clean and renewable energy source, which produces neither green-house effect gas nor noxious waste. In this work, solar photovoltaic cells, which can be used for conversion of solar energy directly into electricity for water pumping in rural agricultural purposes is concentrated. With the help of maximum power point tracking (MPPT) technique the efficient water pumping system is developed. The MPPT algorithms are necessary in PV applications because the maximum power point of a solar panel varies with the irradiation and temperature. So that the use of MPPT algorithms is required in order to obtain the maximum power from a solar array.

Keyword- *photovoltaic system, maximum power point tracker, converters and motors.*

I. INTRODUCTION
Simple but efficient photovoltaic water pumping system with MPPT is presented in this thesis. It provides theoretical studies of photovoltaic’s (PV) and modelling of maximum power point tracking techniques. It also investigates in detail of the maximum power point tracker (MPPT), a power electronic device that significantly increases the system efficiency. The Photovoltaic based DC and AC motor pumping system equipped with Maximum Power Point Tracker (MPPT) for efficient water pumping are discussed in this thesis. We performed comparative tests of the two well-known MPPT the ‘Perturbation and observation' (P&O) and the `Incremental Conductance' (IncCond) algorithms using actual irradiance data for different climate conditions. The subsystem of MPPT is implemented in MATLAB simulation and verifies the functionality and benefits of MPPT. Also established comparisons between both systems in terms of performance parameters such as total energy produced and total volume of water pumped a day. The results indicate that the system with MPPT can significantly improve the performance and the efficiency of PV water pumping system as compared to the one without MPPT. In this thesis the subsystem of MPPT techniques such as duty cycle estimator and slope detector is simulated and the numerical analysis of load matching of PV system with the resistive load under the varying irradiance is done.

II. PHOTOVOLTAIC SYSTEM
PV water pumping system is getting more popular in recent days for water supply especially in remote areas where electricity is economically not available. A single PV cell produces an output voltage less than 1V, about 0.6V for crystalline silicon cells, thus a number of PV cells are connected in series to archive a desired output voltage. When series-connected cells are placed in a frame, it is called as a module. Most of commercially available PV modules with crystalline-Si cells have either 36 or 72 series-connected cells. A 36-cell module provides a voltage suitable for charging a 12V battery, and similarly a 72-cell module is appropriate for a 24V battery. This is because the most of PV systems used to have backup batteries, however today many PV systems do not use batteries; for example, grid-tied systems. Furthermore, the advent of high efficiency DC-DC converters has alleviated the need for modules with specific voltages.

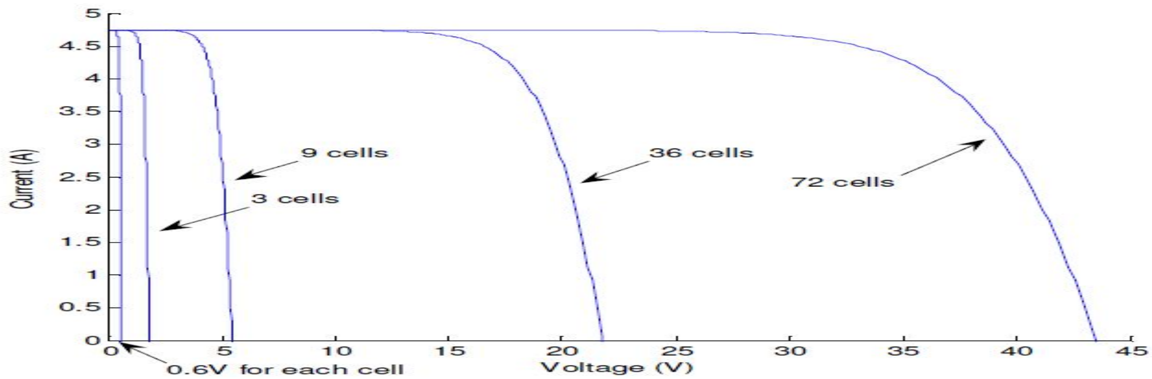

Fig 1.1:- PV cells are connected in series to make up a PV module

PV modules are made from solar cells connected in series and parallel to obtain desired current and voltage level. Solar cells are encapsulated as they have to be weatherproofed and electric connections also have to be robust and corrosion free. The PV cell output is both limited by the cell current and the cell voltage, and it can only produce a power with any combinations of current and voltage on the I-V curve. It also shows that the cell current is proportional to the irradiance.

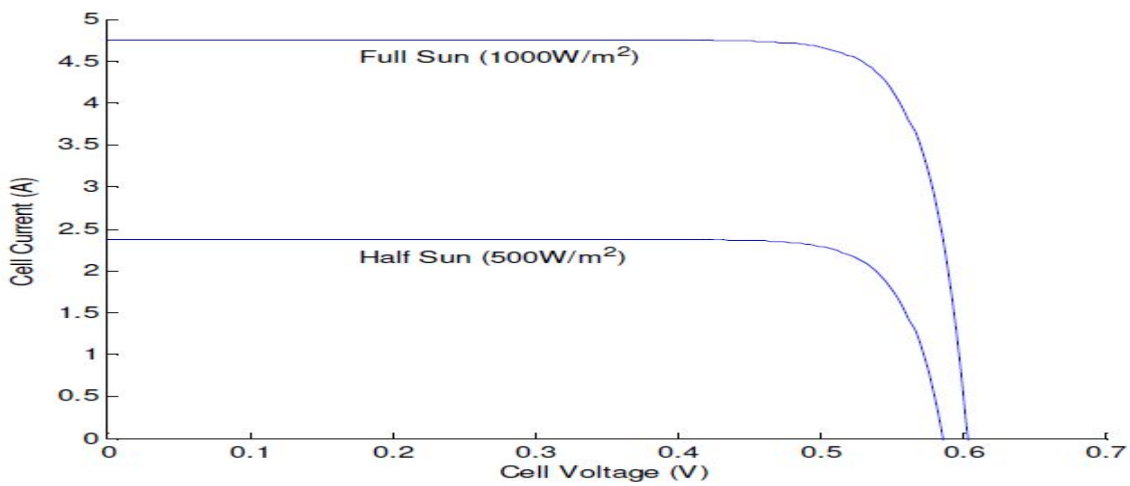

Fig 1.2:- I-V plot of PV cell under two different levels of irradiance (25 C)

The utilisation of photovoltaic conversion to power water pumps is today an emerging technology, characterised by gradually declining costs. The main barrier to a widespread use of PV- systems continues to be their high initial cost. The cost of the photovoltaic parts accounts for 60% of the total investment cost.

Table I. Photovoltaic System Part's Cost in Percentage

PARTS OF PHOTOVOLTAIC SYSTEM	TOTAL COST IN PERCENTAGE
PV-Modules	60 %
Piping	17%
Installation	09 %
Inverter	10 %
Motor / Pump set	04%

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A number of types and sizes of PV-systems are available commercially, in various stages of product development, that meet the range of existing pumping needs. The significant design variations of these systems are centred mainly on:

• The choice of the solar cell material.

• The type of electric motor.

• The type of pump and the method of source/load matching.

Single-stage centrifugal pumps are frequently used for heads of less than 10 meters. For higher heads, either multi-stage centrifugal or positive displacement (piston or progressive cavity) types are more efficient. If the pump is above ground, it is straight coupled to the motor. If submerged, the pump may either be coupled to a submersible motor or driven by a vertical shaft. PV-pumping efficiency has considerably improved. The usual elements of a PV water pumping system are: Photovoltaic array – to provide electricity supply for the motor-pump. This supply could be direct current (DC), usually at 110 volts, or alternating current (AC) which is produced by inverting the DC power to AC power, Motor-Pump set, Battery storage if used – to provide electricity storage and allow pumping in cloudy conditions or at night, Storage tank – normally elevated, making water available at night or when it is cloudy and Maximum power point tracker (MPPT) which forces the PV array to generate its maximum power.

The volume of pumped water is dependent on major factors: The radiation level which is a measure of the sun's available energy, Photovoltaic array area, conversion efficiency of the Photovoltaic array, ambient temperature and pump-motor hydraulic system characteristics. Three different system configurations are currently in use are the first is the directly coupled system where a PV array is directly coupled to a DC motor and a pump. The second system is the battery buffered PV pumping system where a battery is connected across the array to feed the DC motor driving a pump and The third system uses maximum power point tracker (MPPT) or array tracking to improve the efficiency of system. The typical range of sizes for photovoltaic-powered pumps is a few hundred watts to a few kilowatts.

III. SIMULATION OF MPPT

The simulation model of MPPT consist two sub systems.

1. Slope detector
2. Duty cycle estimator

Simulation of Slope Detector:- The inputs of slope detector are sensed PV current I_{PV} and voltage V_{PV}. It first multiplies the inputs in a multiplier and measures PV power which is shown by output 2. Then it compares the value of PV power P(k) to the previous PV power P(k-1) which is delay by some time. If P(k) > P(k-1) then it's output1 gives binary output 1 to up-down counter. If P(k) < P(k-1) then it gives binary output 0 to counter. The proposed model of slope detector is implemented and shown in Figure 1.3

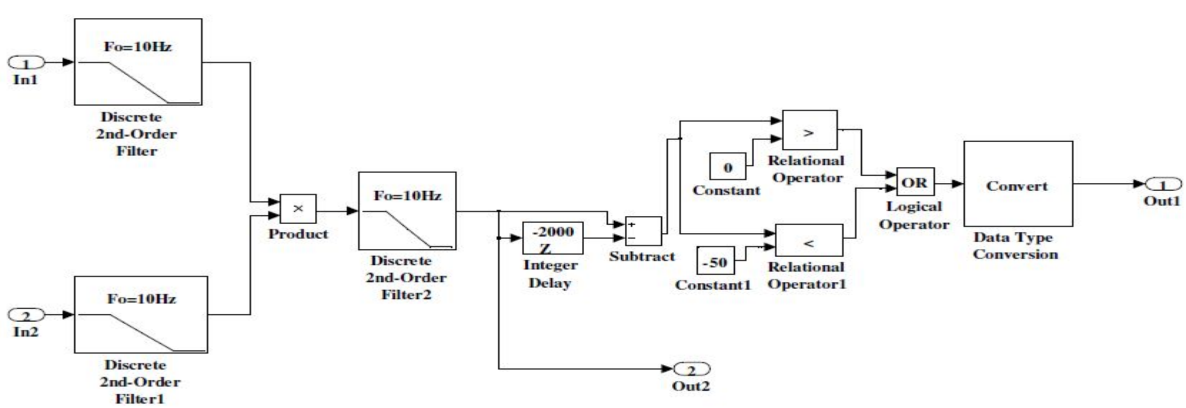

Fig.1.3 Subsystem implementation of slope detector

Simulation model of Duty cycle estimator:- Duty cycle estimators is basically an up down counter it counts up for logic 1 input and counts down for logic 0 input. The counters output is used to control the duty cycle of the buck boost converter. Figure1.4 shows implemented model of duty cycle estimator.

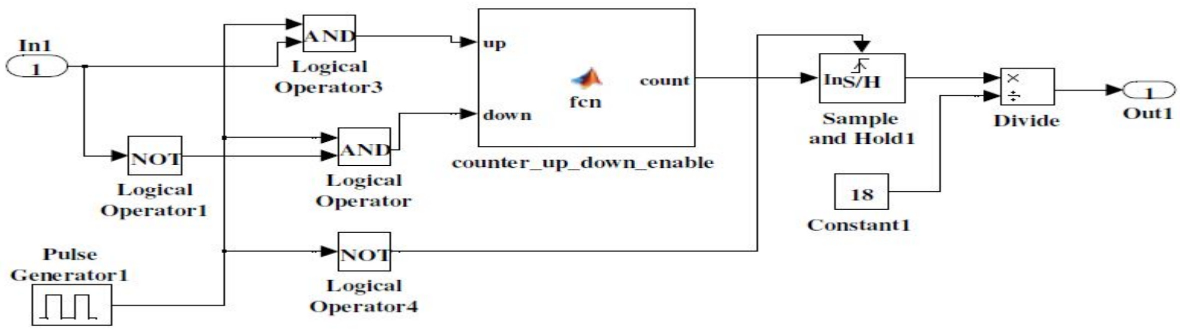

Fig. 1.4 Subsystem implementation of duty cycle estimator

The dynamic efficiency was calculated as follows:

$$\eta_{MPPT} = \frac{P_{PV}}{P_{MPP}}$$

Where P_{PV} is the power obtained from the PV panel and P_{MPP} is the theoretical maximum one. The MPP data obtained when the irradiation changes with steps of 5 W/m2 from 100 to 1000 W/m2 was used to calculate the MPP power (P_{MPP}) in these points and then using MATLAB deriving the equation which best fits the points distribution. The efficiencies under the slopes proposed in table are shown in below.

Table II - Dynamic efficiencies

Efficiency (%)		Slope [W/m 2 s]					
		10	14	20	30	50	100
MPPT	P&O	99.5113	99.5084	99.5027	99.4947	99.4832	99.4618
	InCond	99.5106	99.5039	99.5034	99.4949	99.4844	99.4622

The above values show that the efficiency in case of Incremental Conductance is slightly higher than the Perturb and observe algorithms. The total volume of water pumped for the 12-hour period is also calculated for both systems. The results are tabulated below

Table III: Total volume of water pumped for 12 hours simulated with the radiation data of sunny day.

	With MPPT		Without MPPT
	Loss-less converter	90% Efficiency Converter	

Total Volume Of Water Pumped for 12 Hours (Simulation)	5.305 m3	4.720m3	2.831m3

The results show that MPPT offers significant performance improvement. It enables to pump up to 87% more water than the system without MPPT. Even if the efficiency of converter is set to 90%, it can still pump 67% more water than the system without MPPT.

IV. NUMERICAL ANALYSIS

The maximum power transfer occurs when the input impedance of converter matches with the optimal impedance of PV module, as described in the equation below.

$$R_{in} = R_{opt} = \frac{V_{MPP}}{I_{MPP}}$$

And the duty cycle (D) is

$$D = \frac{1}{1 + \sqrt{\frac{R_{in}}{R_{load}}}}$$

The output voltage of converter is:

$$V_0 = \frac{D}{1-D} . V_s$$

And the output current of converter is:

$$I_0 = \frac{1-D}{D} . I_s$$

The calculation results are tabulated in the tables below. PV module data are obtained from the MATLAB simulation model. Using the equations above, two sets of data are collected for the resistive load of 7 Ω and 15 Ω at the constant module temperature of 25°C.

	PV Module				MPPT			
Irradiance	V_{MPP}	I_{MPP}	P_{max}	R_{in}	D	V_0	I_0	R_{load}
200 W/m2	31.0V	0.89A	27.59W	34.83Ω	0.311	13.93V	1.98A	7 Ω
400 W/m2	32.5V	1.74A	56.55W	18.68Ω	0.380	19.92V	2.84A	7 Ω
600W/m2	33.5V	2.62A	87.77W	12.79Ω	0.425	25.27V	3.49A	7 Ω
800W/m2	34.1V	3.47A	118.33W	9.83Ω	0.458	28.82V	4.12A	7 Ω
1000W/m2	34.6V	4.36A	150.85W	7.93Ω	0.484	32.45V	4.65A	7 Ω

Table IV: Load matching with the resistive load (7 Ω) under the varying irradiance

	PV Module				MPPT			
Irradiance	V_{MPP}	I_{MPP}	P_{max}	R_{in}	D	V_0	I_0	R_{load}

200 W/m2	31.0V	0.89A	27.59W	34.83Ω	0.396	20.32V	1.36A	15 Ω
400 W/m2	32.5V	1.74A	56.55W	18.68Ω	0.473	29.12V	1.94A	15 Ω
600W/m2	33.5V	2.62A	87.77W	12.79Ω	0.519	36.28V	2.42A	15 Ω
800W/m2	34.1V	3.47A	118.33W	9.83Ω	0.550	42.12V	2.81A	15 Ω
1000W/m2	34.6V	4.36A	150.85W	7.93Ω	0.581	47.59V	3.17A	15 Ω

Table V: Load matching with the resistive load (15 Ω) under the varying irradiance

V. CONCLUSION

This work paved a path on the modelling and simulation of the photovoltaic pumping systems using SIMULINK under MATLAB programming environment. The results obtained from the simulation of the system are promising and satisfactory. It is understood that PMDC pumping system is economical for low power range when comparing with the other pumping systems. The discharge rate of water and efficiency of the PMDC pumping system is better than the AC pumping system. This work will be a contribution to the analysis of the photovoltaic pumping system with regards to the results of simulation of the model. This study presents two simple techniques of maximum power point tracking (MPPT) for effective photovoltaic water pumping systems. The subsystem of MPPT are simulates using MATLAB and numerical analysis of load matching can be done on different load resistance. The result shows that the PV model using the equivalent circuit in moderate complexity provides good matching with the real PV module.

REFERENCES

1. *D. Sera, T. Kerekes, R. Teodorescu, F. Blaabjerg, "Improved MPPT method for rapidly changing environmental conditions," in Proc. IEEE International Symposium on Industrial Electronics, vol. 2, pp. 1420-1425, 2006.*
2. *N. Femia, G. Petrone, G. Spagnuolo, M. Vitelli, "Optimization of perturb and observe maximum power point tracking method," IEEE Transactions on Power Electronics, vol. 20, No. 4, pp. 963-973, July 2005.*
3. *W. Xiao, W. G. Dunford, "A modified adaptive hill climbing MPPT method for photovoltaic power systems," in Proc. IEEE PESC, pp. 1957-1963, 2004.*
4. *G.N. Tiwari, Solar Energy, Narosa Publishing House, New Delhi, 2004.*
5. *Rashid, Muhammad H. Power Electronics Handbook Academic Press, 2001.*
6. *John Wiley & Sons "Solar Electricity", Edited by T. Markvart New York, 2000.*
7. *Akihiro Oi "Design and Simulation Of Photovoltaic Water Pumping System" California Polytechnic State University, San Luis Obispo, pp. 14-77, 2005.*
8. *David Sanz Morales "Maximum Power Point Tracking Algorithms for Photovoltaic Applications" Aalto University School of Science and Technology 2010.*
9. *K.H. Hussein, I. Muta, T. Hoshino, M. Osakada, "Maximum photovoltaic power tracking: an algorithm for rapidly changing atmospheric conditions," IEEE Proceedings on Generation, Transmission and Distribution, vol. 142, no. 1, pp. 59-64, 1995.*
10. *A. Hamidata, B. Benyoucef Mathematic models of photovoltaic motor-pump systems Science direct, Renewable Energy 33 pp. 933–942, 2008.*