

Speed Control of Separately Excited Dc Motor Supplied By PV Arrays

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Abstract – In this work an integration of photo voltaic (pv) array connected to dc-dc buck converter will be introduced, this kind of converter play an important role for regulating dc voltage supplied from pv, it reduce the value of voltage according to loads. A separately excited dc motor will be connected to the system as a load, where this motor may exposed to variation in load conditions. PI controller presented as a solution to overcome the changing in load condition, by varying the voltage value it can regulate the motor speed under different sudden change load. (PID) considered a best choice for control circuit in nonlinear system like drive system. the goal of using it derived from adjusting the input voltage to converter under acceptable values. this work proved that using (PI) offering a better performance rather than traditional PID controller in such nonlinear system by enhancing its efficiency and reliability.

Keywords: Separately excited dc motor, fuzzy logic, Buck converter, speed control, PV array

I. INTRODUCTION

Recently the high rates of pollution and carbon emissions resulting from the generation of electrical energy using organic sources have led to thinking about relying on other sources. On the other hand, the urban expansion of cities and the wide distances between them make the process of delivering electricity to users more difficult and more expensive. Thus, researchers and engineers thought about finding other means of generation. Renewable energy sources such as water energy, geothermal energy, wind energy, and solar energy represented the most important of these sustainable sources, and environmentally friendly.[1][2][3][10].

Photo voltaic cells (pv) considered as the major and simplest mean use for generating electricity, it convert the solar wave to electric energy during the day, supplying customers with excess energy, through which they charge suitable batteries as a storage unit for use during the night as back up sources. Photovoltaic can deliver power to device or customer through dc –dc buck –boost, or buck converters to control and regulate both voltage and current feeding dc load. This load may be fraction to hundred watt for example motors, light, heating etc...[3][9].that it is innovative, it is used in the section "Research Method" to describe the step of research and used in the section "Results and Discussion" to support the analysis of the results [3]. An other suggestion of speed control of dc motor presented by Tanjim Tarannum depends on D ANFIS controller, by propped the model he

got an efficient speed regulation by increasing the rise time and reduced the peak of ripple [11]. Ujjwal Kumar present regulation of separately excited dc motor using different method of Tuning Conventional Controllers such as PI, and Z-N method, by using both methods gives a good regulation performance for motor but the second considered the better due to its fast response, superior dynamic reaction and minimum overshoot.[12]

II. Theory

Photovoltaic system is a system that change the sunlight into electricity using many of solar Cells, each cell consist of semiconductor switches. The electrical energy generated from a single photovoltaic cell may be sufficient to supply a small load, such as a simple lighting element or a voltage regulator for a specific circuit, but in loads with a high demand for power, this cell is unable to supply enough energy, so many of these cells are assembled in what is called a module to be later in arrays. Photovoltaic, which includes a group of which produces a few tens or hundreds of watts, figure (1) shown the construction of photovoltaic array [1] [8] [9].

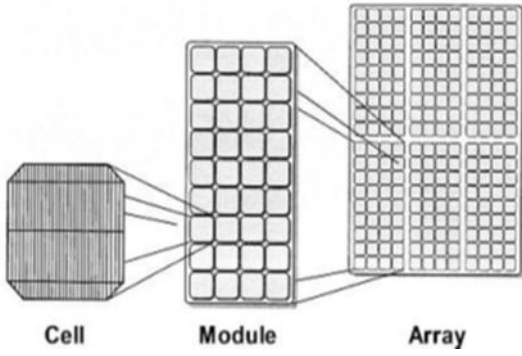
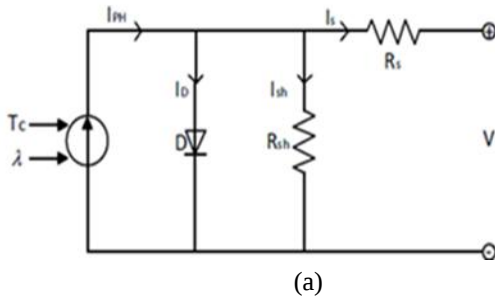


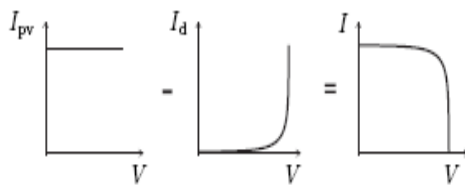
Figure 1. Construction of photo voltaic

III. Methodology

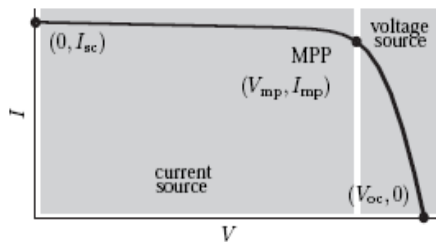
Understanding the work of a photocell requires studying its equivalent circuit and its properties, as shown in Figures 2a and 2b, 2c , which shows the relationship between both voltage and current and the greatest power resulting that can be obtained due to them, which is called maximum power point (MPP) . [3][5][9]



(a)



(b)



(c)

Figure 2.(a) equivalent circuit of solar cell, (b) V-I characteristics of solar cell, (c) MPP characteristic [3][5][9]

Where:

V : is voltage across cell terminal

V_{oc} : is open circuit voltage

I_{sc} short circuit current

I : is diode current

I_{ph} : photovoltaic current

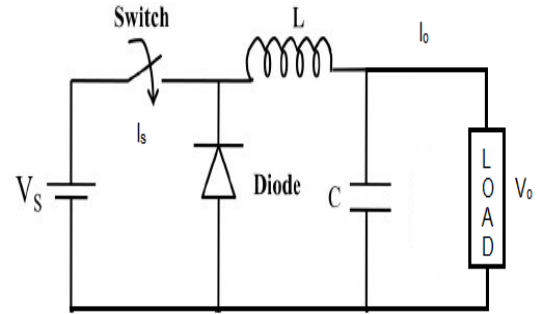


Figure 3. . Buck converter equivalent circuit

IV. Analysis

It is defines power electronics converters that chopping dc power wave. It can be consider as small power supply for light load, this type of converter based on power semiconductor switches that characterize with rapid response at normal state operation condition. Buck converter includes transistor as on / off switches functioning at high switching frequency, additionally dc power supply as input sources then control scheme to regulate the operation state.[1] [5]. Figure (3) shown the dc-dc buck converter scheme

Separately excited dc motor

Direct current (DC) motors are common type of electrical machine, they used in different field of industrial, transportation, traction, robotics etc.... These motors characterized by simple construction, easy control. Different type of dc motors can be classified depending on field winding connection such as self and separately excited motor. The later kind is used in this work. As it an electrical machine dc motor can realized by mathematical equations in (4 and 5) describing itself to present its performance [7]

$$L_a \frac{di}{dt} = -i_a R_a - K\omega + v_a \quad (4)$$

$$J \left(\frac{d\omega}{dt} \right) = -K i_a R_a - B\omega - T_L \quad (5)$$

Where

v_a : Armature voltage

i_a : Armature current

T_L : Load torque

J : motor inertia

B : damping factor

L_a : armature inductance

System model and simulation

Using matlab Simulink the suggested case studied in this work-introduced, firstly the system consist of photovoltaic array as a power supply feeding dc-dc buck converter, the later operate as voltage chopper to regulate the output delivered form (pv) to separately excited dc motor. The proposed system built without any control system, Just for examine the operate of PV array how to generate the voltage that feeds buck converter. Figure (4) shows the studied system

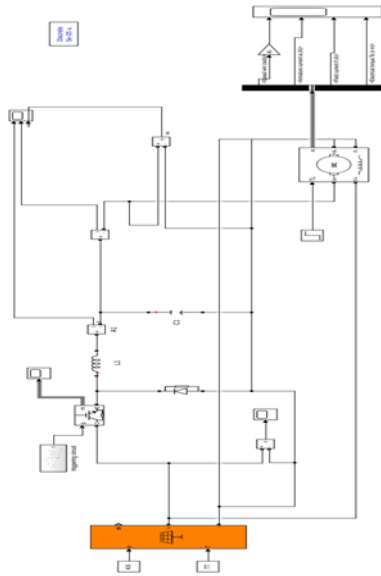


Figure 4. Whole system, PV array, buck converter feeding separately excited dc motor without controller

Simulation results

The operation principle of this circuit described as follow. A lot of number of photo voltaic cell connected together as an array, they collect the energy from solar wave then converting it to electrical energy. To supply this power to motor (load) it passes through power electronic device (IGBT) that operates as switch controlling the power flow depending on the duty cycle. The latter represent the signal applied on transistor gate through specific time called t_{on} , then voltage will be chopped according to the way used for firing gate. The new output voltage waveform delivered from switch then is feeding a separately excited dc motor riding light load .The following figures describe the system performance without controller

At beginning, the first result tested was to achieve the performance operation characteristic of solar pv array (V-I) and (P-V) in figure (5)

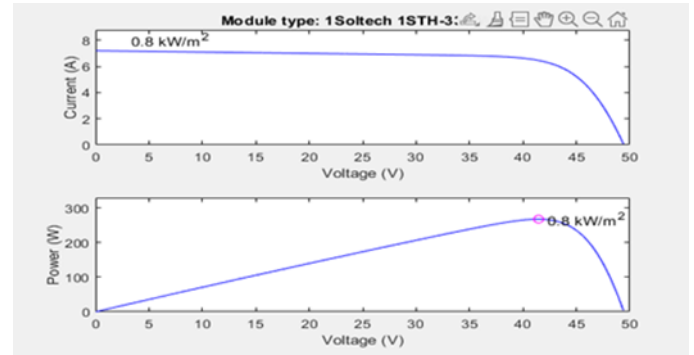


Figure 5. Characteristic of PV Array

Operation without controller for system

The following results describe the motor performance of motor under uncontrolled status for normal condition of operation , Figure (6) shows the motor speed at uncontrolled status

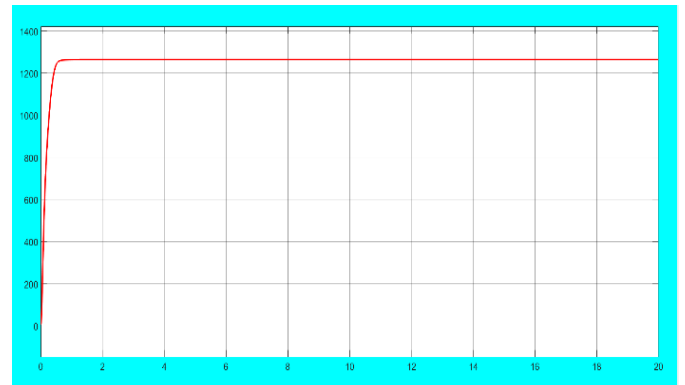


Figure 6. Motor speed (RPM) of motor with out controller

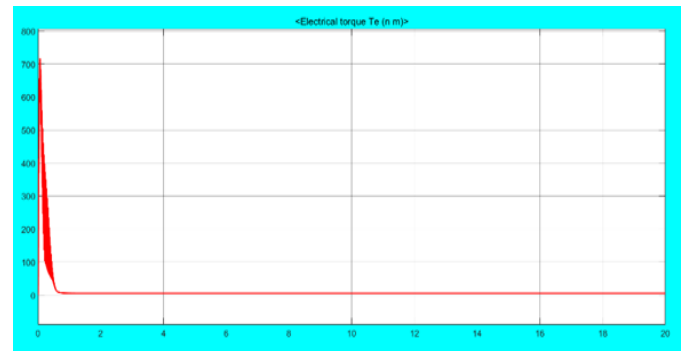


Figure 7. Motor torque (N.M) of motor without controller

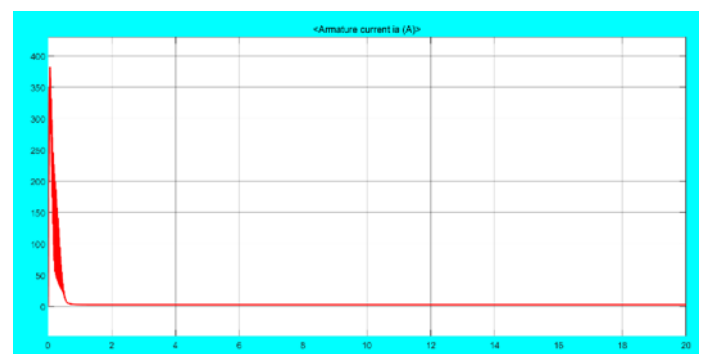


Figure 8. Motor armature current (A) of motor without controller

Operation with controller for system

Adding control circuit to the system represent next step for building the whole structure needed to regulate the motor speed. Proportional –Integral-derivative (PID) considered the common methods used in control system. This controller characterized by simplicity in operation, additionally no need to understanding the control theory deeply. Figure 5 shown the hole scheme of system controller [10]

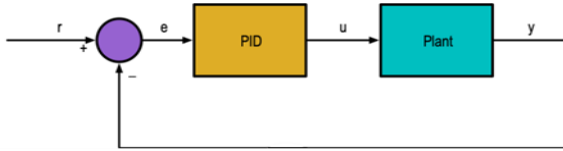


Figure 9. Scheme of system controller

In addition, PI offers a minimum value of steady state error (SSE) of system adding to eliminating the offset SSE leading to reach it at zero value. PI can describe its operation using the following equation

$$U(t) = (e(t) + \int e(t) dt) \quad (6)$$

$$U(t) = K_p * e(t) + K_i + \int e(t) dt \quad (7)$$

ki : refers to integral gain constant.

kp : refers to proportional gain constant

* the higher proportional gain the faster system response

The designed control scheme connected to the suggested system to adjust the buck converter output to achieve target speed at sudden load change as shown in figure (10)

In the next figures (11) , system performance will be presented at case when PID controller connected to buck converter for adjusting its operation duties for abnormal status

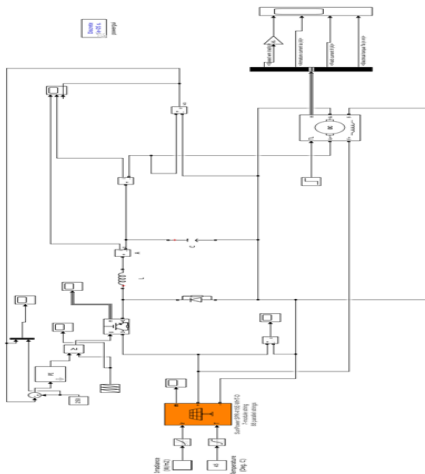


Figure 10. Whole system, PV array, buck converter feeding separately excited dc motor with controller

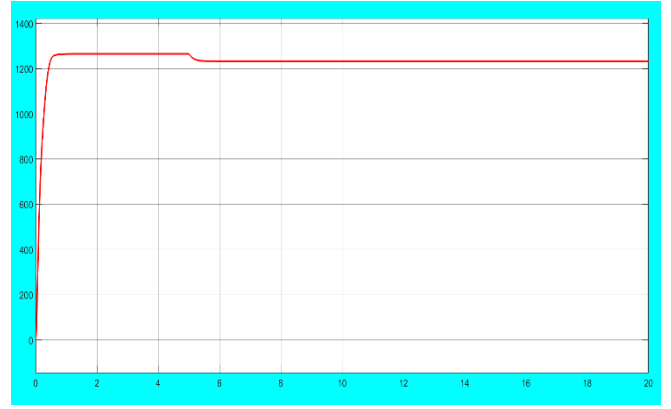


Figure 11. Motor speed (RPM) of motor with PI controller

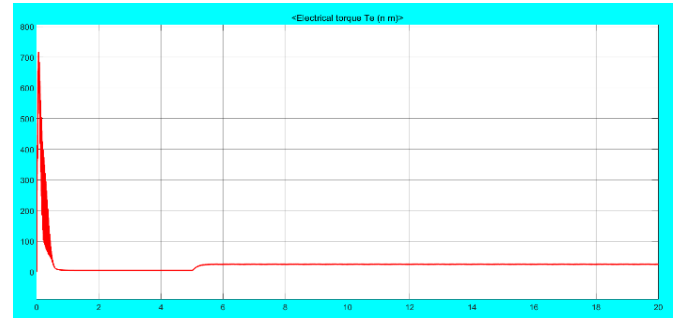


Figure 12. Motor torque (N.M) of motor with controller

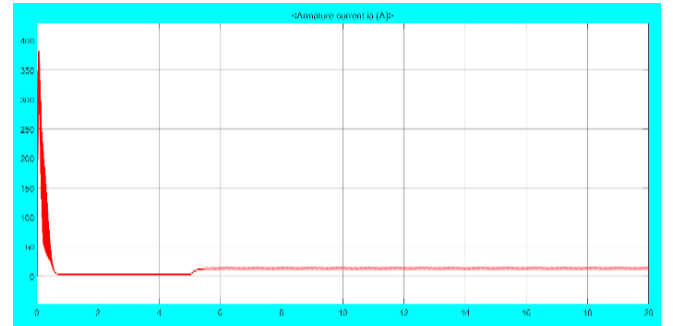


Figure 13. Motor armature current (A) of motor with controller

V. Conclusions

In this work, an examination of proportional –integral (PI) controller presented .It shows its effects on system performance of separately excited dc motor speed fed from photo voltaic (PV) . the search pointed to show the effect of controller on speed regulation at sudden change of load . Where dc motor fed from pv its operate normally according to operation principle of motor .Controller established strength in keeping motor speed under changing load conditions., as well as minimizing the steady state error and over shoot for the targeted value .Using closed loop controller successfully tracked the required speed .In summery this work donate in mechatronics and renewable energy systems as a sustainable energy source and automation process.

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REFERENCES

- [1] M Ettappan, G Maheswaran, V Vimala, K Somasundaram, J Vishnupriyan , Design of Buck Converter and PV Module for Solar Powered Sailing Boat, Journal of Physics: Conference Series 2027 (2021) 012023 doi:10.1088/1742-6596/2027/1/012023
- [2] Chao-Ying WangYang-Chieh OuChih-Feng WuChih-Feng WuMuh-Tian ShiueMuh-Tian Shiue, A voltage-mode DC-DC buck converter with digital PID controller . Conference: 2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD .DOI: 10.1109/FSKD.2015.7382315
- [3] F. Yusivar, M. Y. Farabi, R. Suryadiningrat, W. W. Ananduta, and Y. Syaifudin. , Buck-Converter Photovoltaic Simulato. International Journal of Power Electronics and Drive System (IJPEDS). Vol.1, No.2, December 2011, pp. 156~167
- [4] M.Dinesh, K.R.Venkatesan, Dr.J.Baskaran, Design, Control and Simulation of Buck Converter using PID controller and Reference Regulator Technique. International Journal on Recent Technologies in Mechanical and Electrical Engineering (IJRMEE). Volume: 2 Issue: 10,2015
- [5] Niaj Murshed, Md. Salman Khan Tushar, Suman Chowdhury, Power Performance Analysis of PV Module with DC to D DC Buck Converter.Advanced journal of graduate research. Volume 8, Issue 1, pp. 27-39, July 2020
- [6] M. Gupta and S. P. Phulambrikar, Design and Analysis of Buck Converter. International Journal of Engineering Research & Technology .Vol. 3 Issue 3, March – 2014
- [7] A.L. Hashmia SH. Dakheel. Speed Control of Separately Exited DC Motor Using Artificial Neural Network. Journal of Engineering and Development, Vol. 16, No.4, Dec. 2012 ISSN 1813- 7822
- [8] Zhiqiang Gao, Song Li, Xuesong Zhou, Youjie Ma, An Overview of PV System. Proceedings of 2016 IEEE International Conference on Mechatronics and Automation August 7 - 10, Harbin, China.
- [9] Snehamoy Dhar, R Sridhar, Varun Avasthy, Modeling and Simulation of Photovoltaic Arrays. www.iitk.ac.in
- [10] Victoria Melissa Serrano Rodriguez , PID Controller Tuning and Adaptation of a Buck Converter. PhD thesis. ARIZONA STATE UNIVERSITY August 2016.
- [11] Tanjim Tarannum , Intelligent Speed Control of DC Motor using ANFIS D Controller. 1st International Conference on Advances in Science, Engineering and Robotics Technology 2019 (ICASERT 2019)
- [12] Ujjwal Kumar , Devendra Dohare, Separately Excited DC Motor Speed control of using various Tuning Conventional Controllers. International Research Journal of Engineering and Technology (IRJET). p- ISSN: 2395-0072Volume: 02 Issue: 08 | Nov-2015