Speed Control of Separately Excited DC Motor Supplied by PV Arrays

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Abstract— *In recent day modern power, system and industrial application witnessed great interest by engineering and scientist. Converters used with these applications also developed leading to improve efficiency, power management, cost, reliability and others. Bidirectional dc-dc converters are the base for all electric systems, which depends on dc power flow through networks or grids. In this work different kind of bidirectional converter are introduce, As well as the operation principle with limitation will propose. This review include several parts covered converter topology, operations, application, system storage units and control strategy.*

Keywords— dc-dc converter, Bidirectional converter, renewable energy PV array, electric vehicle.

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]. Another suggestion of speed control of dc motor presented by Tanjim Tarannum depends on D ANFIS controller, by proposed 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. PHOTOVOLTAIC ARRAYS

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, Fig (1) shown the construction of Photovoltaic array [1] [8] [9].

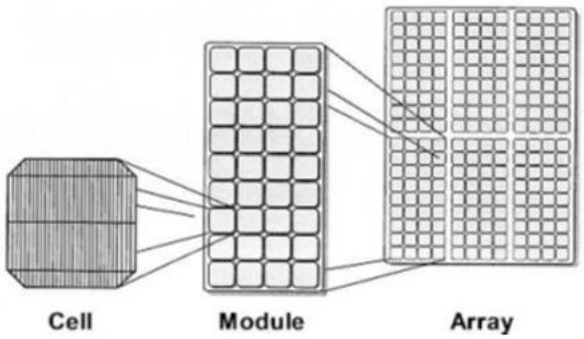

FIGURE 1: Construction of photo voltaic

2.1 Characteristic of solar cell:

Understanding the work of a photocell requires studying its equivalent circuit and its properties, as shown in Fig 2.(a, b, c), 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]

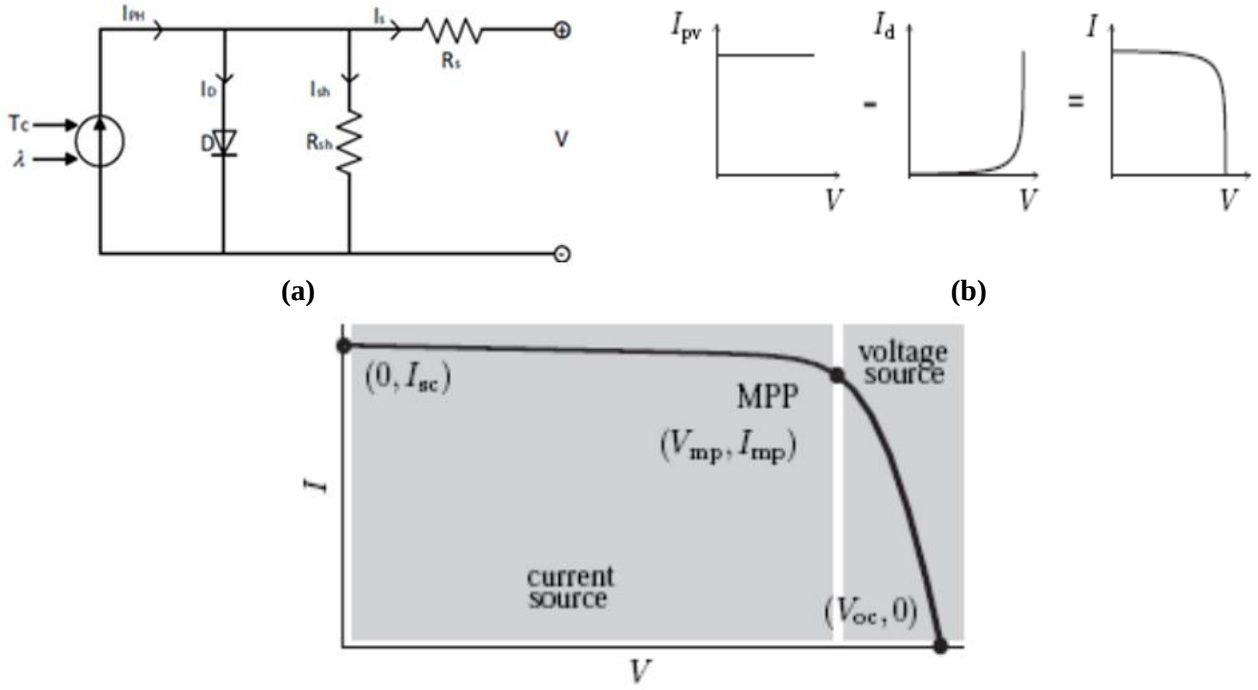

FIGURE 2: (a) Equivalent circuit of solar cell, (b) V-I characteristics of solar cell, (c) MPP characteristic [3][5][9]

V: Isvoltage across cell terminal

Voc: is open circuit voltage

Isc: Short circuit current

I: is diode current

Iph: Photovoltaic current

III. DC-DC BUCK CONVERTER

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].

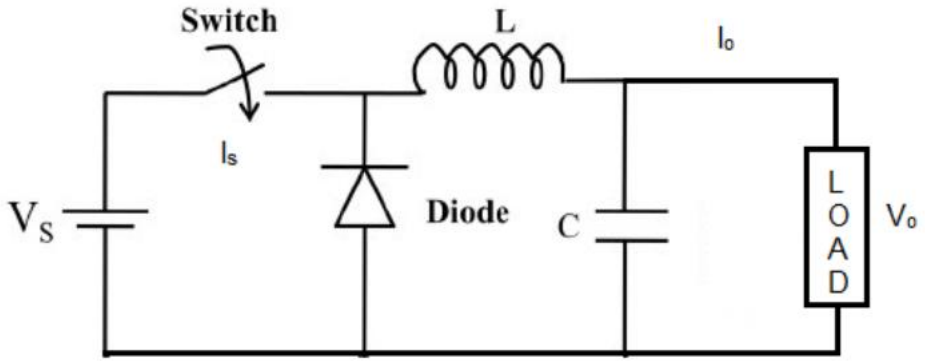

FIGURE 3: Shown the dc-dc buck converter scheme

Buck converter can describe using equations written as shown [3] [5] [6]

$$Vo = D*Vin \quad (1)$$

Vo is output voltage of converter

Vin is input voltage supplied by any source across converter

$$D = ton/T \quad (2)$$

D is duty cycle

ton is on time operation of converter

T is period of operation

$$\Delta VC = Vo\ (Vin - Vo)/(8LC\ f2\ Vin) \quad (3)$$

ΔVC is ripple in voltage

L is circuit inductance

C is circuit capacitance

f is switching frequency of transistor (switch)

IV. 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]

$$La\ di/dt = -ia\ Ra - Kw + va \quad (4)$$

$$J\frac{dw}{dt} = -Ki_aR_a - BWT_L \quad (5)$$

Where

$\boldsymbol{v_a}$: Armature voltage

i_a : Armature current

T_L: Load torque

J: Motor inertia

B: Damping factor

La: Armature inductance

V. 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 buck converter operates as a voltage chopper to regulate the output voltage from the photovoltaic (PV) array before delivering it to the 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. Fig.4. shows the studied system.

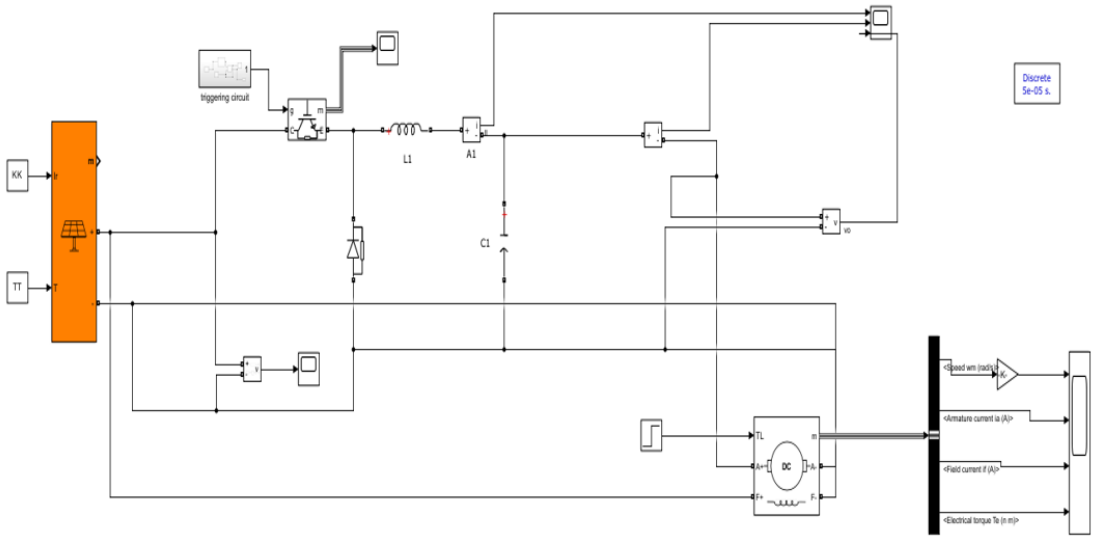

FIGURE 4: Whole system, PV array, buck converter feeding separately excited dc motor without controller

VI. 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 ton, 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).

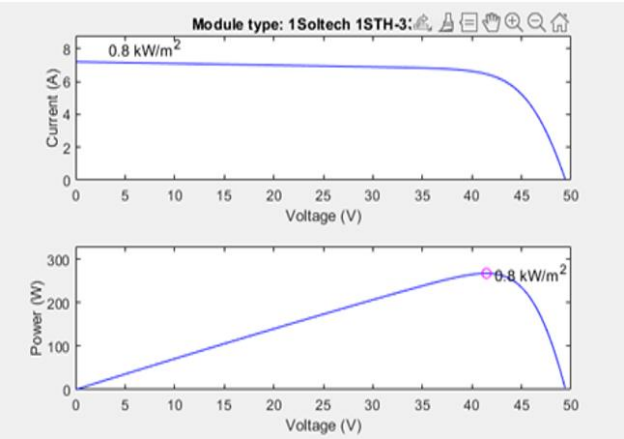

FIGURE 5: Characteristic of PV Array

6.1 Operation without controller for system:

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

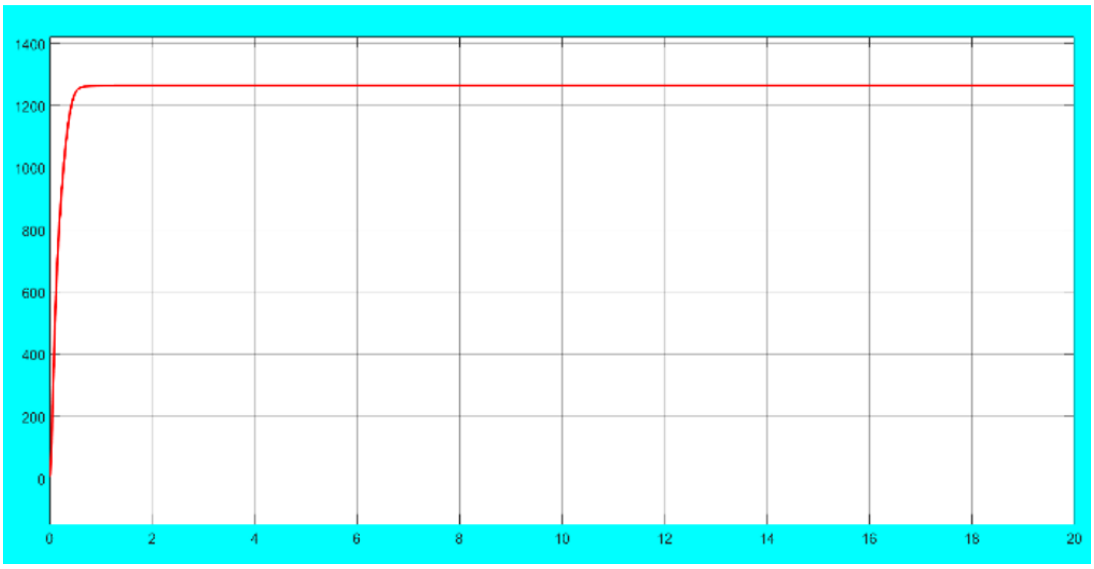

FIGURE 6: Motor speed (RPM) of motor without controller

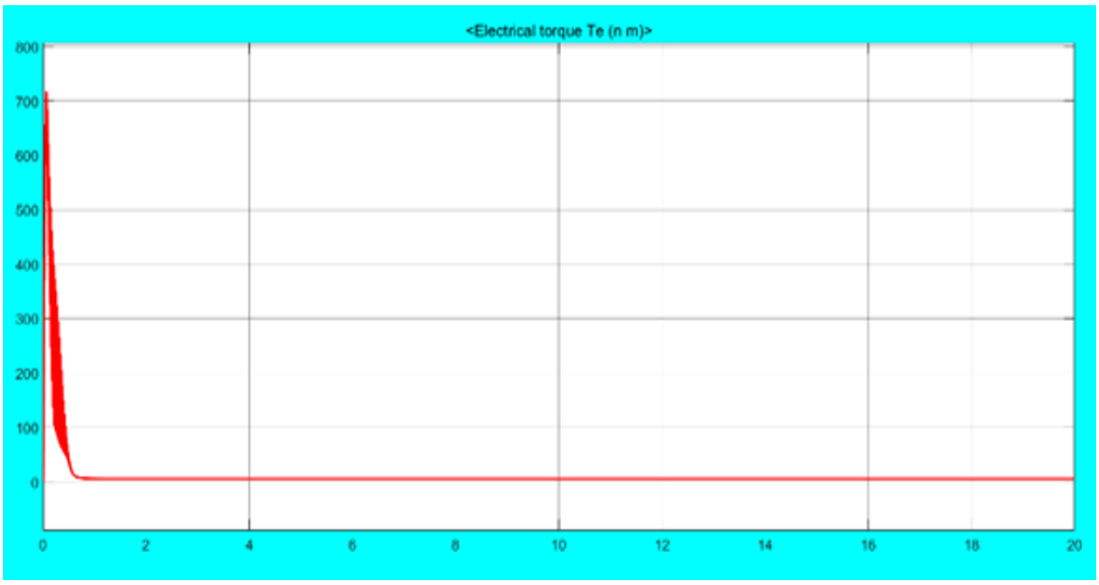

FIGURE 7: Motor torque (N.M) of motor without controller

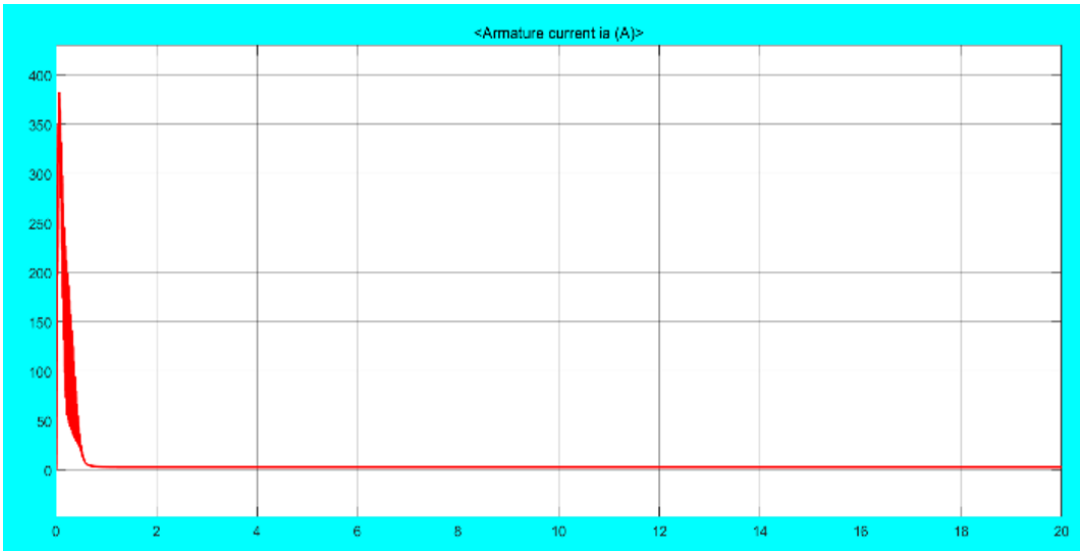

Figure 8: Motor armature current (A) of motor without controller

6.2 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 whole scheme of system controller [10].

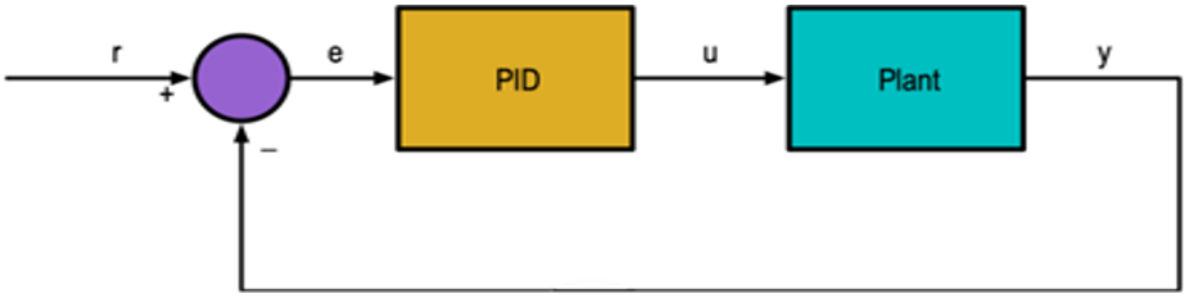

FIGURE 9: Scheme of system controller

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

$$\boldsymbol{U_{(t)} = (e_{(t)} + \int e_{(t)}\, dt)} \quad (6)$$

$$\boldsymbol{U_{(t)} = K_p * e_{(t)} + K_{i+\int e_{(t)} dt)}} \quad (7)$$

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 fig.11, system performance will be presented at case when PID controller connected to buck converter for adjusting its operation duties for abnormal status.

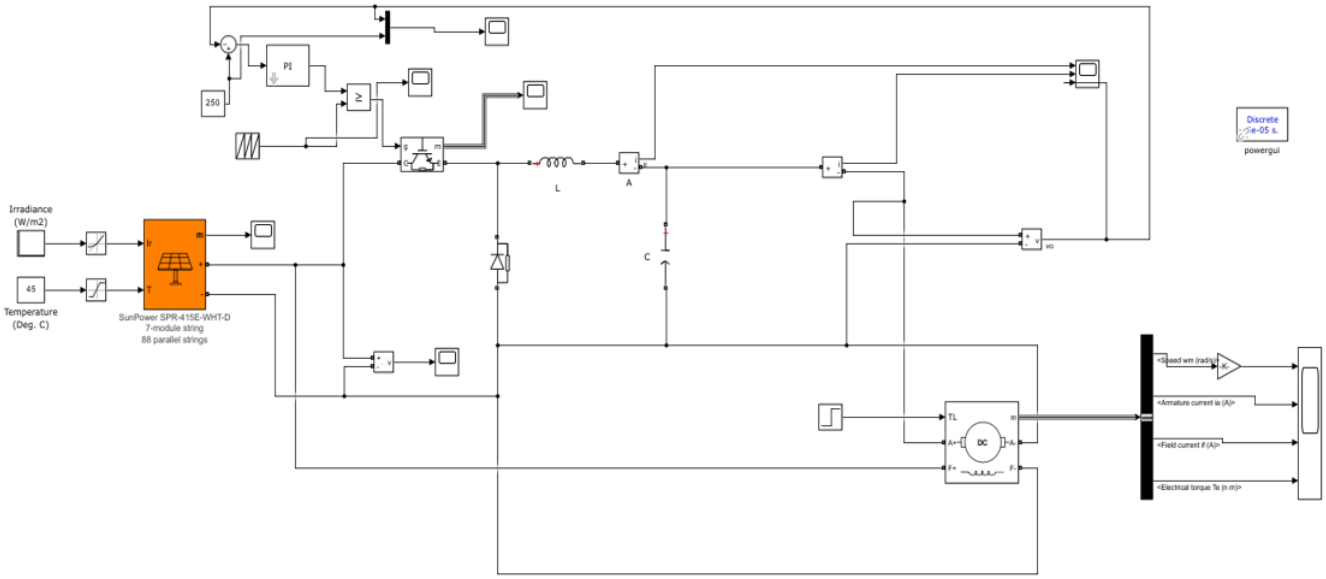

FIGURE 10: Whole system, PV array, buck converter feeding separately excited dc motor with controller

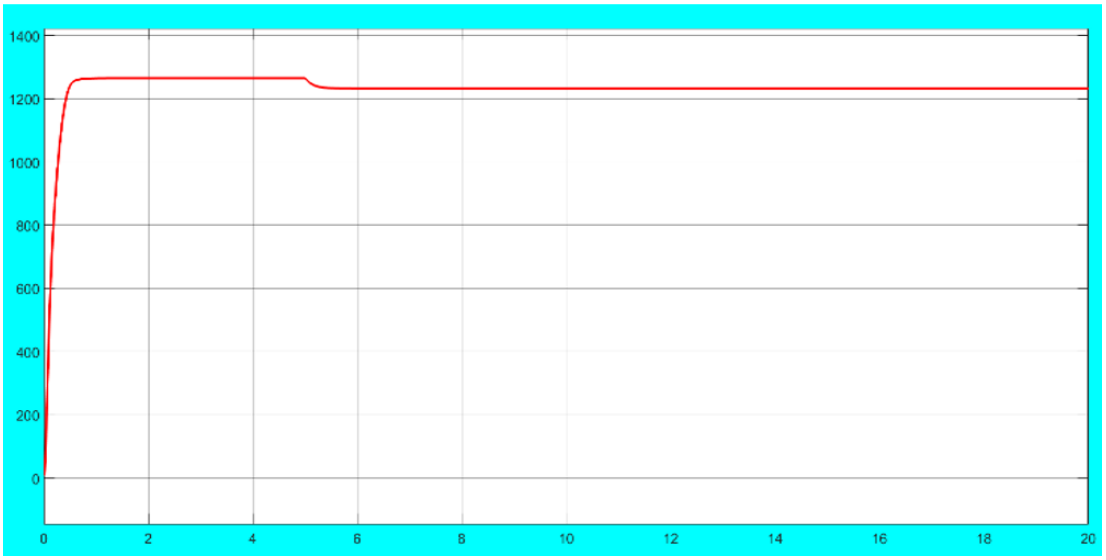

FIGURE 11: Motor speed (RPM) of motor with PI controller

Figure (12) and (13) show the torque and armature current of motor with controller circuit.

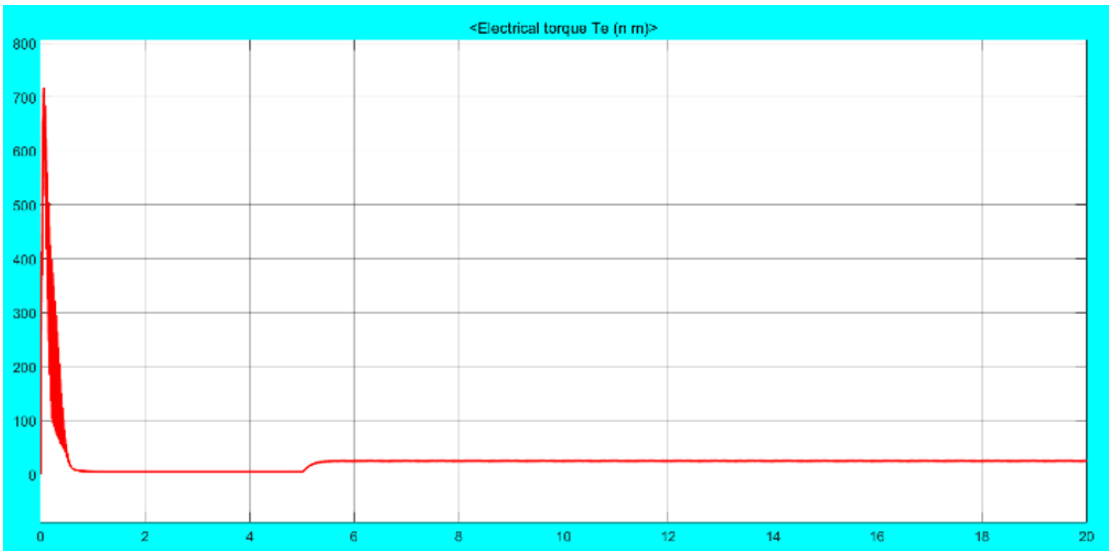

FIGURE 12: Motor torque (N.M) of motor with controller

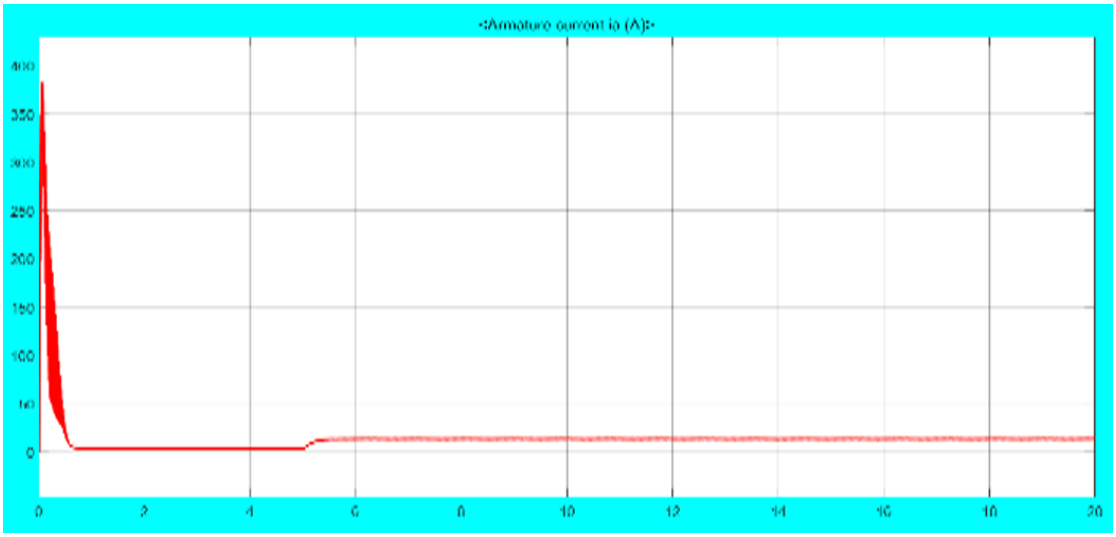

FIGURE 13: Motor armature current (A) of motor with controller

VII. CONCLUSION

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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