

Figure 8(i) Perturb and Observe Algorithm simulation [35]

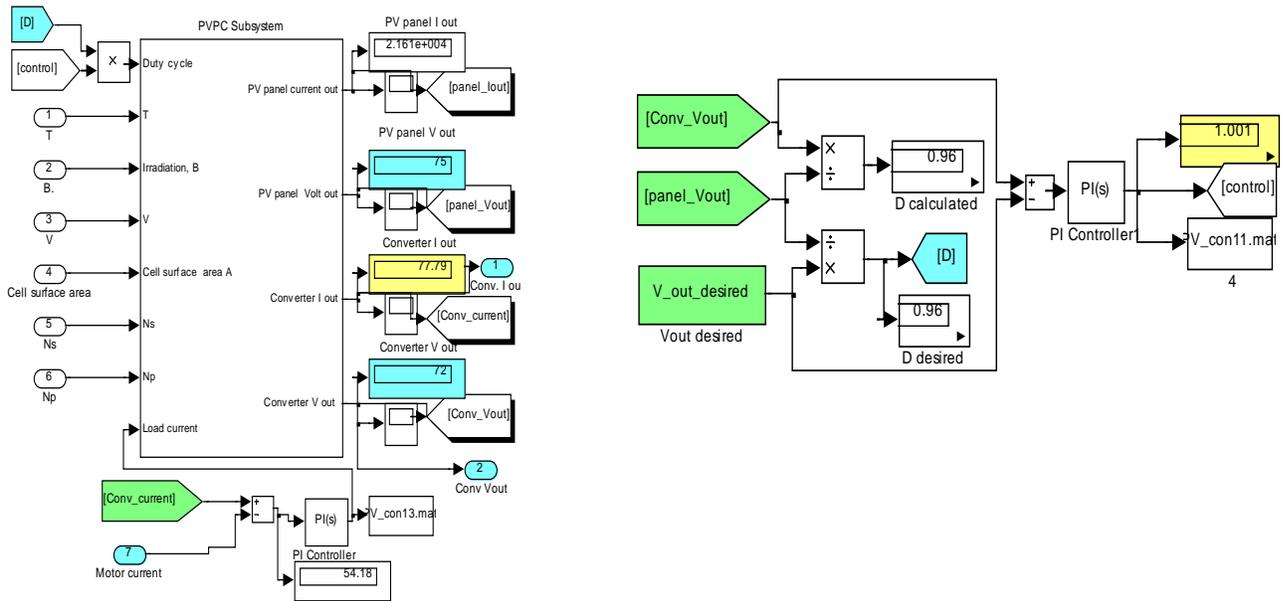


Figure 8(g) Twp separate PI controllers (right and below)for controlling PV output characteristics

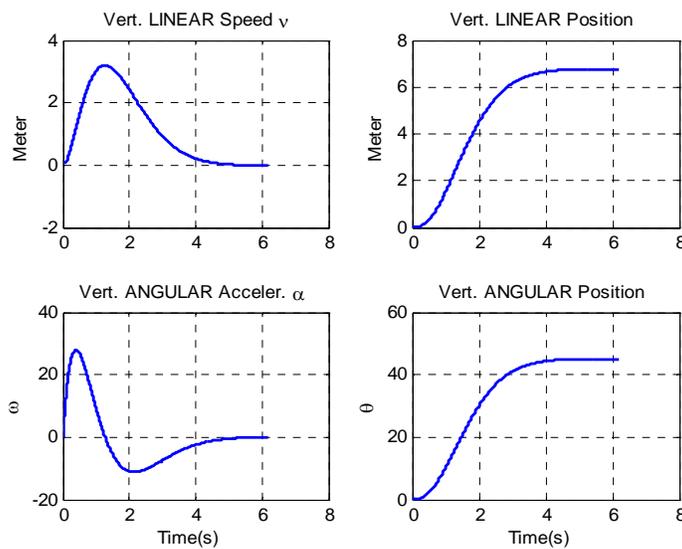


Figure 9(a) vertical up-down motion response curves; linear position, angular position, linear speed and angular acceleration all versus time

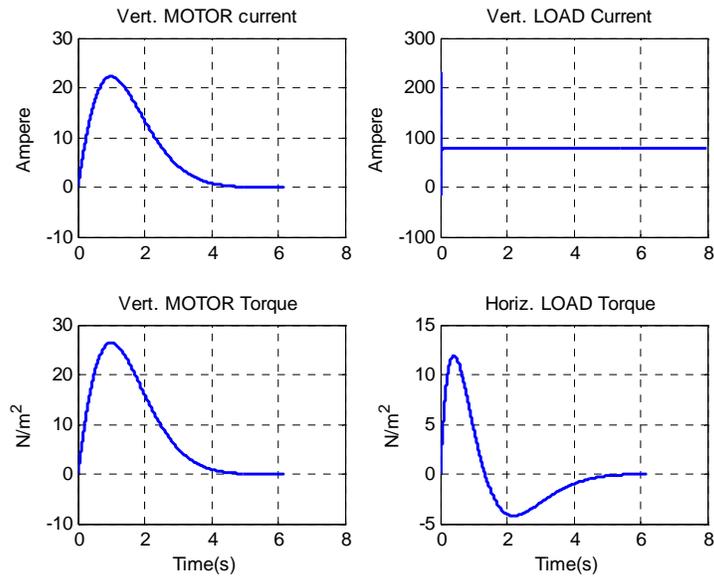


Figure 9(b) vertical up-down response curves of consumed current, load current, motor generated torque and load torque all versus time

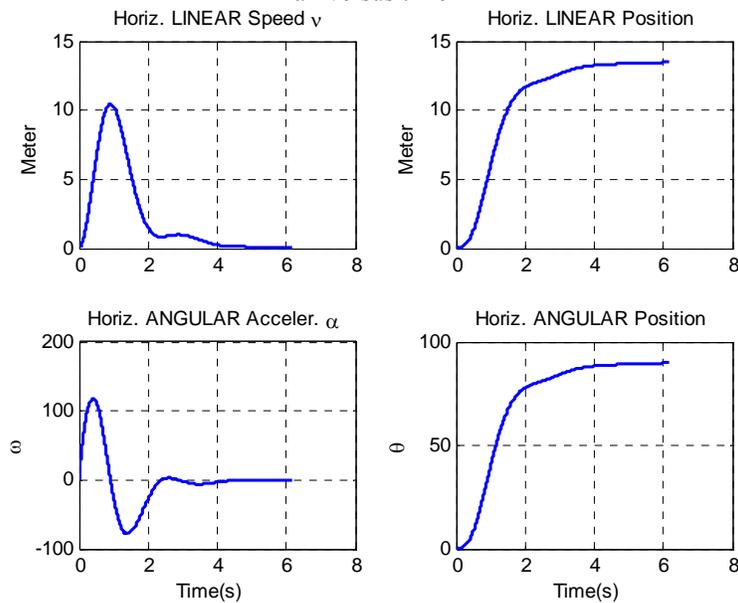


Figure 9(c) Horizontal right-left motion response curves of linear position, angular position, linear speed and angular acceleration all versus time

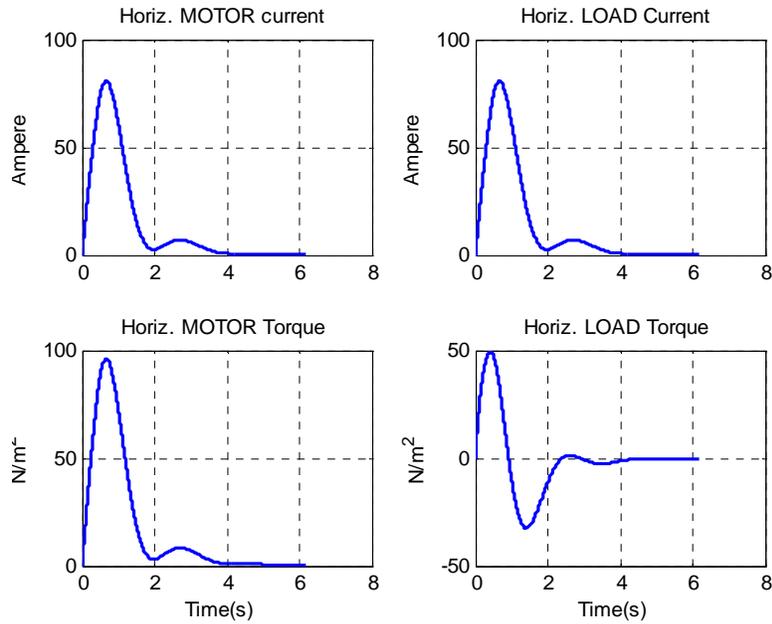


Figure 9(d) Horizontal right-left motion response curves of consumed current, load current , motor generated torque and load torque all versus time

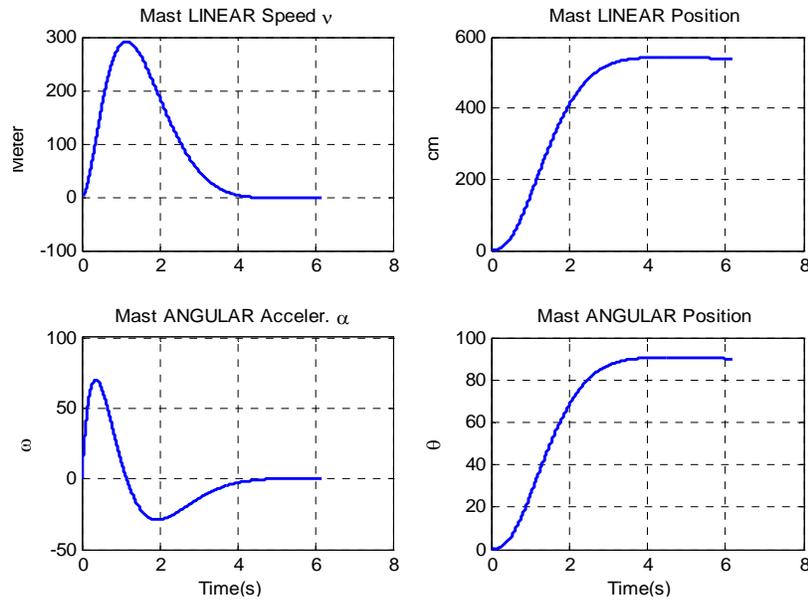


Figure 9(e) Mast motion response curves of linear position, angular position, linear speed and angular acceleration all versus time

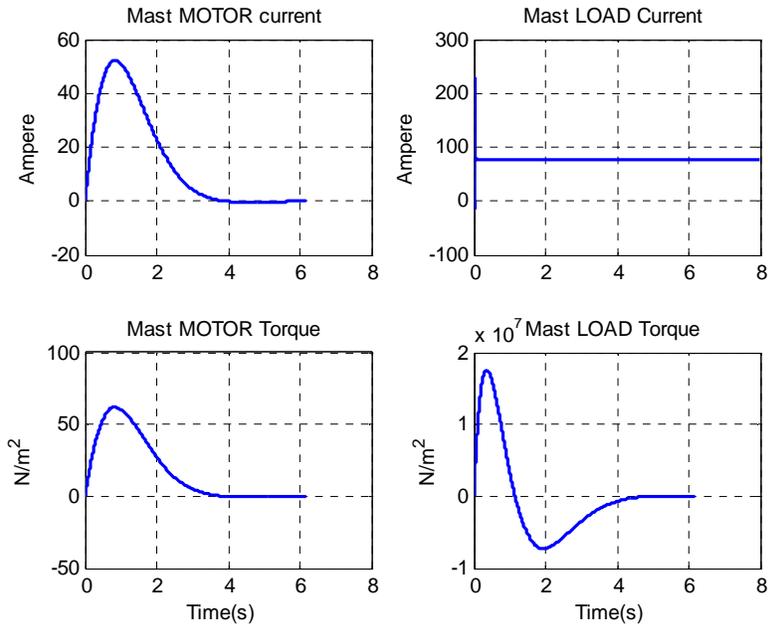


Figure 9(f) Mast response curves of consumed current, load current, motor generated torque and load torque all versus time

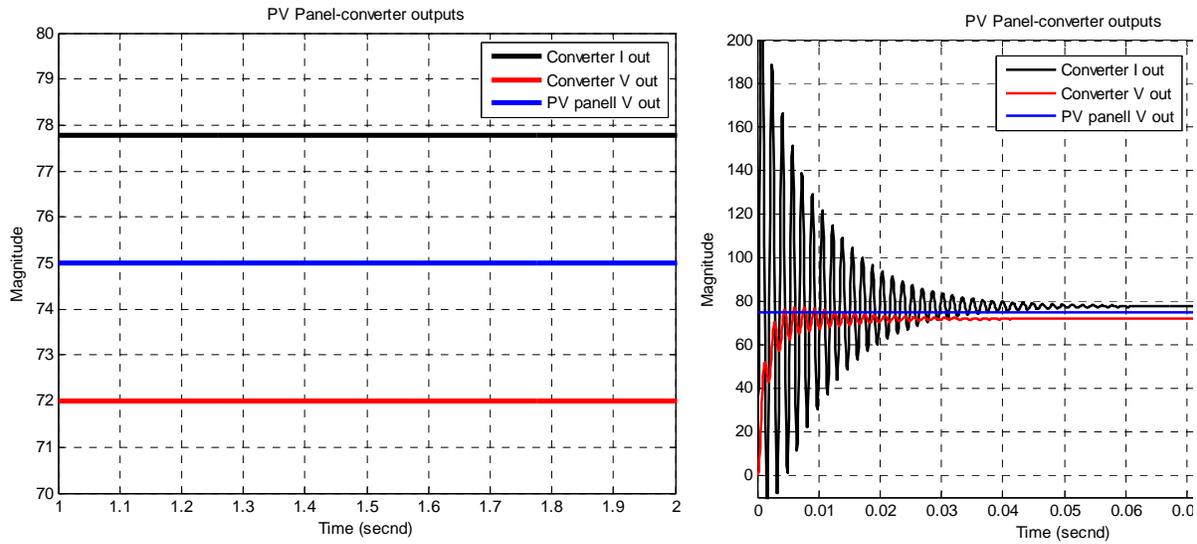


Figure 9(g) PV-converter system outputs;

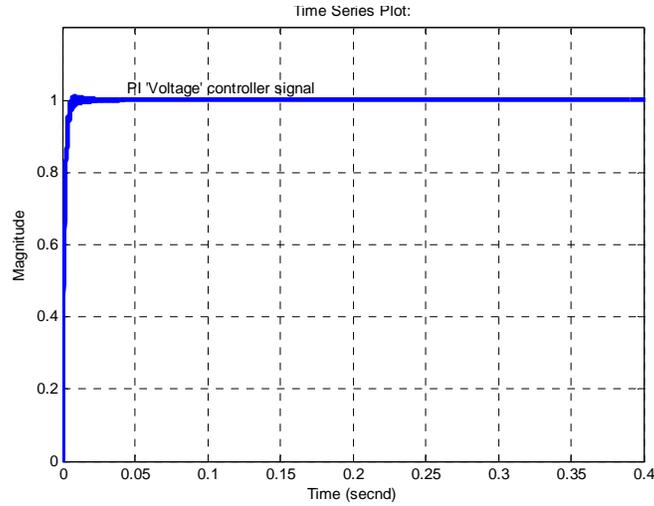


Figure 9(h) PI control signal

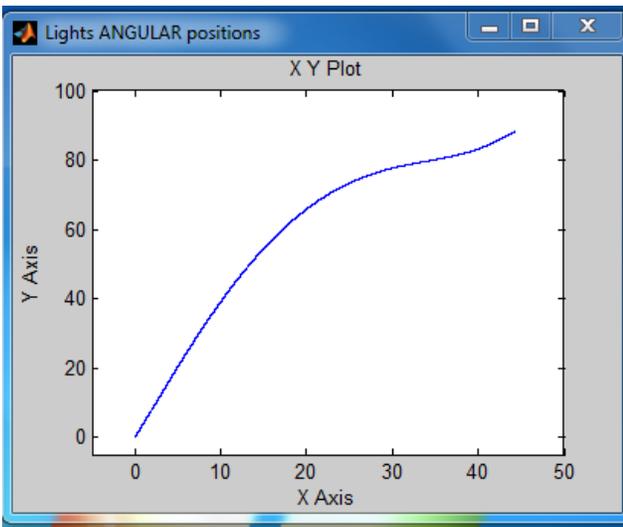


Figure 10(a) the plot of relating *angular* positions of both vertical and horizontal linear speeds

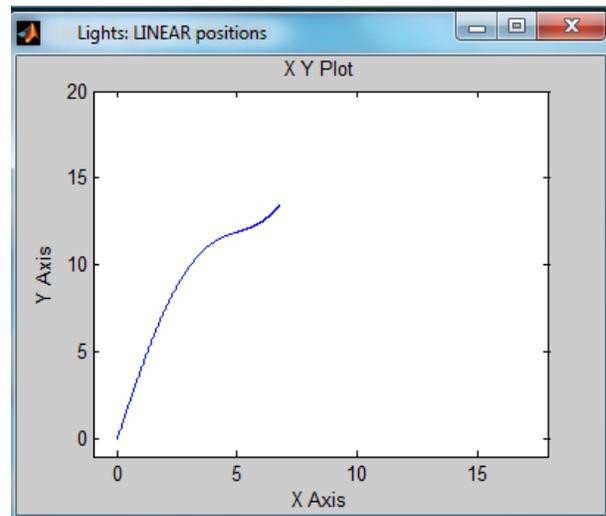


Figure 10(b) the plot of relating *linear* positions of both vertical and horizontal motions

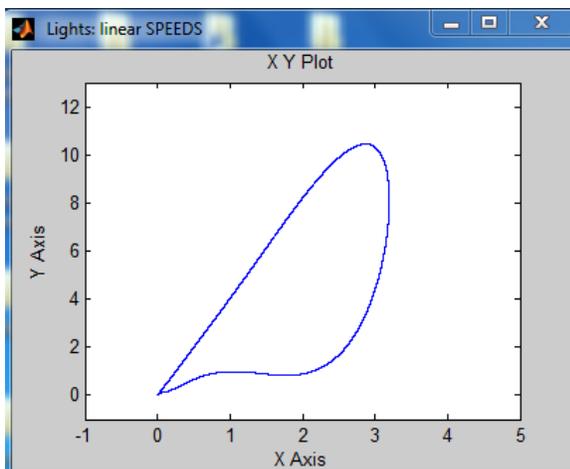
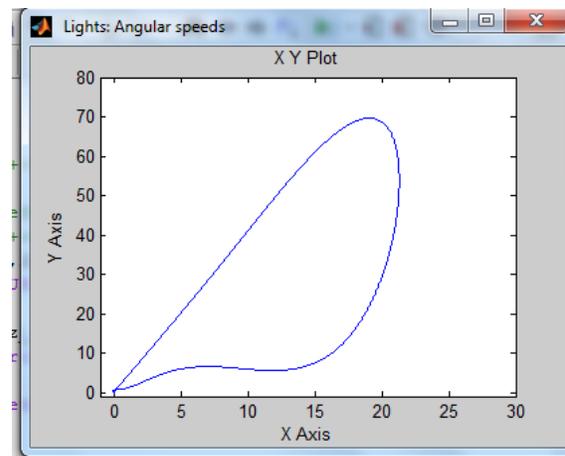


Figure 10(c) the plots of relating *linear speeds* and angular speeds of both vertical and horizontal motions



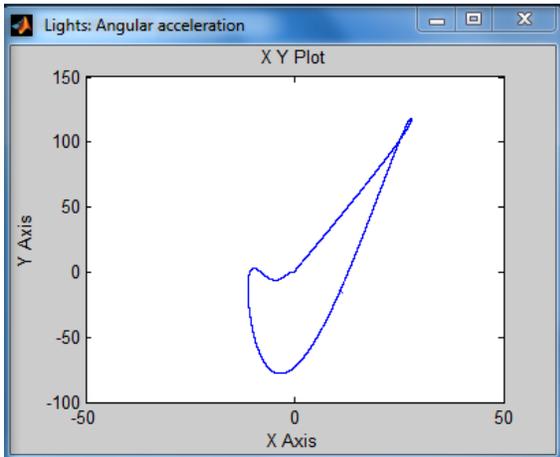


Figure 10(d) the plot of relating angular *accelerations* of both vertical and horizontal motions

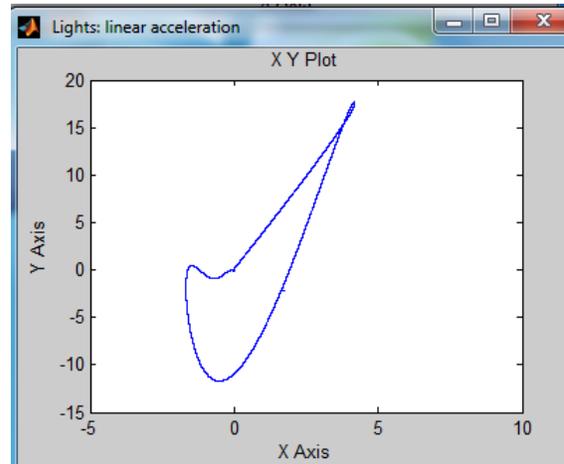


Figure 10(e) the plot of relating *linear acceleration* positions of both vertical and horizontal motions

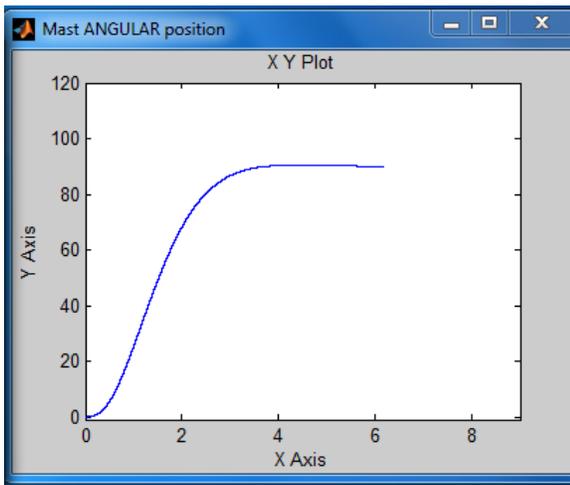


Figure 10(f) mast angular position versus time

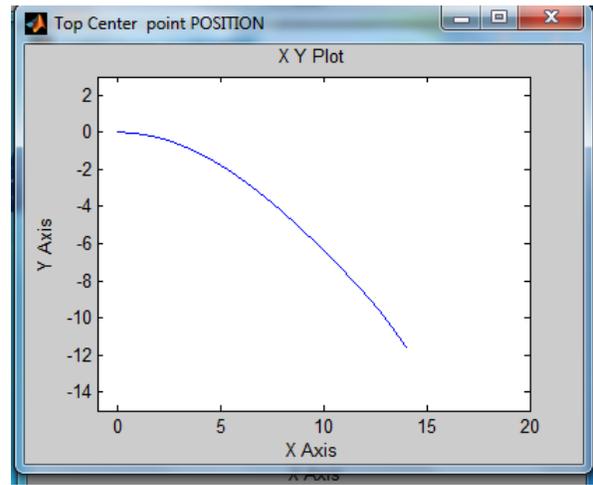


Figure 10(g) lights assembly center point motion versus time

Table 1(a) Simulation results of each subsystem and whole SEDDMRP system for straight line motion

PVPC system inputs		PV cell outputs		PV Panel outputs		Converter outputs		DC machinee outputs	
β	300	Voltage	0.5 V	Voltage	75 V	Voltage	72	Input voltage	24 V
T	75	Current	1.37 A	Current	46.01	Current	77.79	Right-left output Ang. position.	90
D	0.5	Fill factor	0.1374			P-out	5594.4	Up-down output Ang. position	45
A	0.0025	Power out	0.6835					Mast Ang. position	90
N_s	150	Power in	0.5						
N_p	70	Efficiency	0.7315						

Conclusions

A new generalized and refined model for Mechatronics design of pure standalone solar light tower and some considerations regarding design, modeling and control solutions are proposed. The proposed SLT system model consists of eight main subsystems, each subsystem, is mathematically described and corresponding Simulink sub-model is developed, then an generalized whole SLT system model is developed by integrating all sub-models, the generalized model is developed to allow designer to have the maximum output data (numerical and graphical) to select, model, simulate, analyze and evaluation the overall SLT system and each subsystem outputs characteristics and performance, for desired overall and/or either subsystem's specific outputs, under various PV subsystem input operating conditions, to meet particular SLT system requirements and performance. The obtained results show the simplicity, accuracy and applicability of the presented designs and models to help in Mechatronics design of SEV system .

Table 2 Nomenclature and nominal characteristic of SLT subsystems

Lights DC machine parameters	
$V_{in}=24\text{ V}$	Input voltage to DC machine
$K_t=1.188\text{ Nm/A}$	Motor torque constant
$R_a = 0.1557\Omega$	Motor armature Resistance
$L_a=0.82\text{ MH}$	Motor armature Inductance,
$J_m=0.271\text{ kg.m}^2$	Geared-Motor Inertia
$b_m=0.271\text{ N.m.s}$	Viscous damping
$K_b=1.185\text{ rad/s/V}$	Back EMF constant,
$n=1$	Gear ratio
$J_{equiv}\text{ kg.m}^2$	The total equivalent inertia,
$b_{equiv}\text{ N.m.s}$	The total equivalent damping,
$K_{pot}=0.2667$	Tachometer constant, for right-left motion
$K_{pot1}=0.0.5333$	Tachometer constant, for up-dawn motion
$\omega=\text{speed/r, rad/s}$	Shaft angular speed rad/sec
T_{shaft}	The torque produced by motor
η	The transmission efficiency
T_{shaft}	The torque, produced by the driving motor
Mast DC machine parameters	
M,m, Kg	The mass of the mast
$V_{in}=24\text{ V}$	Input voltage to DC machine

$K_t=3.1882\text{Nm/A}$	Motor torque constant
$R_a = 1\ \Omega$	Motor armature Resistance
$L_a=1\text{ MH}$	Motor armature Inductance,
$J_m=1\text{ kg.m}^2$	Geared-Motor Inertia
$b_m=1\text{ N.m.s}$	Viscous damping
$K_b=3.1882\text{rad/s/V}$	Back EMF constant,
$V_{in}=24\text{ V}$	Input voltage to DC machine
$C_d=0.80$	Aerodynamic drag coefficient
C_L	The coefficient of lift, with values
$Cr=0.5$	The rolling resistance coefficient
$\rho, \text{ kg/m}^3$	The air density at STP, $\rho =1.25$
$a, \text{ m/s}^2$	linear Acceleration
$G, \text{ m/s}^2$	The gravity acceleration
$v, \text{ m/s}$	The linear speed.
B	Mast reference area
L	lift,
A_f	Mast frontal area
K_p	Proportional gain
K_I	Integral gain
Z_0	PI controller zero
P_m	The power available in the wheels of the vehicle.
T_{Total}	The total resistive torque, the torque of all acting forces.
Solar cell parameters	
$I_{sc}=8.13\text{ A}, 2.55\text{ A}, 3.8$	The short-circuit current, at reference temp 25°C
I_A	The output net current of PV cell (<i>the PV module current</i>)
$I_{ph}\text{ A}$	The light-generated photocurrent at the nominal condition (25°C and 1000 W/m^2),
$E_g := 1.1$	The band gap energy of the semiconductor
$V_t = KT / q$	The thermo voltage of cell. For array : $(V_t = N_s KT / q)$
$I_s, \text{ A}$	The reverse saturation current of the diode or leakage current of the diode
$R_s=0.001\text{ Ohm}$	The series resistors of the PV cell, it they may be neglected to simplify the analysis.
$R_{sh}=1000\text{ Ohm}$	The shunt resistors of the PV cell

V	The voltage across the diode, output
$q=1.6e-19 C$	The electron charge
$B_o=1000 W/m^2$	The Sun irradiation
$\beta =B=200 W/m^2$	The irradiation on the device surface
$Ki=0.0017 A/^{\circ}C$	The cell's short circuit current temperature coefficient
$V_o= 30.6/50 V$	Open circuit voltage
$N_s= 48 , 36$	Series connections of cells in the given photovoltaic module
$N_m= 1 , 30$	Parallel connections of cells in the given photovoltaic module
$K=1.38e-23 J/oK;$	The Boltzmann's constant
$N=1.2$	The diode ideality factor, takes the value between 1 and 2
$T= 50 Kelvin$	Working temperature of the $p-n$ junction
$T_{ref}=273 Kelvin$	The nominal reference temperature
Buck converter parameters	
$C=300e-6; 40e-6 F$	Capacitance
$L=225e-6; .64e-6 H$	Inductance
$Rl=RL=7e-3$	Inductor series DC resistance
$rc= RC=100e-3$	Capacitor equivalent series resistance, ESR of C ,
$V_{in}= 24 V$	Input voltage
$R=8.33; 5 Ohm;$	Resistance
$R_{on}=1e-3;$	Transistor ON resistance
$KD=D= 0.5, 0.2,$	Duty cycle
$Tt=0.1 , 0.005$	Low pass Prefilter time constant
V_L	Voltage across inductor
I_C	Current across Capacitor

REFERENCES

[1] Farhan A. Salem, Ahmad A. Mahfouz, A Proposed Approach to Mechatronics Design and Implementation Education-Oriented, Innovative Systems Design and Engineering , Vol.4, No.10, pp 12-39,2013.

[2] Hordeski, Michael F. *Dictionary of energy efficiency technologies*. USA: CRC Press. pp. 175–176. ISBN 0-8247-4810-7, 2004.

[3] Grondzik, Walter T.; Alison G. Kwok, Benjamin Stein, John S. Reynolds Mechanical and Electrical Equipment for Buildings, 11th Ed.. USA: John Wiley & Sons. pp. 555–556. ISBN 0-470-57778-9, 2009.

[4] Light Tower, operator's manual, PI 7.6 LP TL / PI 9.5 LP TL / PI 9.9 P TL / PI 14.3 P TL, PI (precise industries), www.pi-dubai.com

[5] TEREX light Construction, operational manual, series AL4000D1 light tower operation, service and parts manual After Serial Number: FKF-13923, REVISION B SEPTEMBER 2006.

[6] G. Walker, "Evaluating MPPT converter topologies using a MATLAB PV model," Journal of Electrical & Electronics Engineering, Australia, IEAust, vol.21, No. 1, 2001, pp.49-56.

[7] Francisco M. González-Longatt, Model of Photovoltaic Module in Matlab , 2DO Congreso Iberoamericano de estudiantes de ingeniería eléctrica, electrónica y Computación (II CIBELEC 2005).

[8] Huan-Liang Tsai, Ci-Siang Tu, and Yi-Jie Su, Development of Generalized Photovoltaic Model Using Matlab/Simulink, Proceedings of the World Congress on Engineering and Computer Science, October 22 - 24, 2008, San Francisco, USA 2008.

[9] J. Surya Kumari, Ch. Sai Babu, Mathematical Modeling and Simulation of Photovoltaic Cell using Matlab-Simulink Environment, International Journal of Electrical and Computer Engineering (IJECE) Vol. 2, No. 1, pp. 26~34 February 2012.

[10] Sergio Daher, Jurgen Schmid and Fernando L.M Antunes, “Multilevel Inverter Topologies for Stand- Alone PV Systems” *IEEE Transactions on Industrial Electronics*.Vol.55, No.7, July 2008.

[11] Soeren Baekhoeg Kjaer, John K.Pedersen Frede Blaabjerg “A Review of Single –Phase Grid-Connected Inverters for Photovoltaic Modules” *IEEE Transactions on Industry Applications*, Vol.No.5, September/October 2005..

[12] J.M.A. Myrzik and M.Calais “*Sting and Module Intigratrdr Inverters for Single –Phase Grid-Connected Photovoltaic Systems – Review*” IEEE Bologna Power Tech conference, June 2003..

- [13] Solar direct , <http://www.solardirect.com/pv/pvlist/pvlist.htm> .
- [14] G. Walker, "Evaluating MPPT converter topologies using a MATLAB PV model," *Journal of Electrical & Electronics Engineering*, Australia, IEAust, vol.21, No. 1, 2001, pp.49-56.
- [15] Lorenzo, E. (1994). *Solar Electricity Engineering of Photovoltaic Systems*. Artes Graficas Gala, S.L., Spain.
- [16] J. A. Gow and C. D. Manning, "Development of a photovoltaic array model for use in power-electronics simulation studies," *IEE Proceedings- Electric Power Applications*, vol. 146, no. 2, 1999, pp. 193-199.
- [17] I. H. Altas and A.M. Sharaf, "A Photovoltaic Array Simulation Model for Matlab-Simulink GUI Environment," *IEEE, Clean Electrical Power, International Conference on Clean Electrical Power (ICCEP '07)*, June14-16, 2007, Ischia, Italy.
- [18] M. G. Villalva, J. R. Gazoli, E. Ruppert F. , modeling and circuit-based simulation of photovoltaic arrays, *Brazilian Journal of Power Electronics*, vol. 14, no. 1, pp. 35--45, 2009
- [19] S. Sheik Mohammed, Modeling and Simulation of Photovoltaic module using MATLAB/Simulink, *International Journal of Chemical and Environmental Engineering*, Volume 2, No.5 , 2011,
- [20] S. W. Angrist, , *Direct Energy Conversion*, Allyn and Bacon, Inc., 4th edition, 1982, pp. 177-227.
- [21] O. Wasynczuk, "Dynamic behavior of a class of photovoltaic power systems," *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-102, no. 9, 1983, pp. 3031-3037.
- [22] J. C. H. Phang, D. S. H. Chan, and J. R. Philips, "Accurate analytical method for the extraction of solar cell model parameters," *Electronics Letters*, vol. 20, no. 10, 1984, pp.406-408.
- [23] G. Walker, "Evaluating MPPT converter topologies using a Matlab PV model", *Journal of Electrical & Electronics Engineering*, Australia, Vol.21, No. 1. (2001), pp. 49-56.
- [24] F. González-Longatt, "Model of photovoltaic in Matlab™" 2do Congreso Iberoamericano de Estudiantes de Ingeniería Eléctrica, Electrónica y Computación (II CIBELEC 2005). Puerto la Cruz – Venezuela. Abril 2006.
- [25] Akihiro Oi. Doctoral thesis. Design and simulation of photovoltaic water pumping system, California Polytechnic State University , 2005
- [26] Ramos Hernanz, JA., Campayo Martín, J.J, Zamora Belver, I., Larrañaga Lesaka, J., Zulueta Guerrero, E. Puelles Pérez, E. 'Modelling of Photovoltaic Module, *International Conference on Renewable Energies and Power Quality(ICREPQ'10)* Granada (Spain), 23th to 25th March, 2010.
- [27] N. Pandiarajan and Ranganath Muthu, Mathematical Modeling of Photovoltaic Module with Simulink, *International Conference on Electrical Energy Systems (ICEES 2011)*, 3-5 Jan 2011
- [28] J. A. Gow and C. D. Manning. Development of a photovoltaic array model for use in power-electronics simulation studies. *Electric Power Applications, IEE Proceedings*, 146(2):193–200, 1999.
- [29] Farhan A. Salem, Ahmad A. Mahfouz , A Proposed Approach to Mechatronics Design and Implementation Education-Oriented, *Innovative Systems Design and Engineering* , Vol.4, No.10, pp 12-39,2013.
- [30] Farhan A. Salem, Dynamic and Kinematic Models and Control for Differential Drive Mobile Robots, *International Journal of Current Engineering and Technology* , Vol.3, No.2 , pp253-263 (June 2013).
- [31] Farhan A. Salem, Refined modeling and control for Mechatronics design of mobile robotic platforms, *Estonian Journal of Engineering*, 19, 3, 212–238,2013.
- [32] Farhan A. Salem, Mechatronics motion control design of electric machines for desired deadbeat response specifications, supported and verified by new MATLAB built-in function and Simulink model, *European Scientific Journal* December 2013 edition vol.9, No.36 2013.
- [33] Ahmad A. Mahfouz, Mohammed M. K., Farhan A. Salem , Modeling, Simulation and

Dynamics Analysis Issues of Electric Motor, for Mechatronics Applications, Using Different Approaches and Verification by MATLAB /Simulink (I). *I.J. Intelligent Systems and Applications*, pp39-57 ,05, 39-572013.

- [34] Farhan A. Salem , New refined Model for Mechatronics design of solar electric mobile robotic platforms, *International Journal of Scientific & Engineering Research*, Volume 5, Issue 6, June-2014 . 2013.
- [35] Samer Alsadi, Basim Alsayid ,Maximum Power Point Tracking Simulation for Photovoltaic Systems Using Perturb and Observe Algorithm, *International Journal of Engineering and Innovative Technology (IJEIT)*, Vol 2, Issue 6, pp80-85,December, 2012
- [36] Min Zhang , Modeling and Simulation of Hybrid Electric Vehicle Power Systems , *SAE technical paper series* , 2007-01-1592World CongressDetroit, Michigan, April 16-19, 2007
- [37] <http://www.savepower.com.au/products/solar-powered-mobile-lighting-tower/>
- [38] Farhan A. Salem , Mechatronics Design of Solar Tracking System *International Journal of Current Engineering and Technology* , Vol.3, No.2 (June 2013)

Mohammed M. K. : Now with Taif University, Dept. of Mechanical Engineering, Taif, SA

Farhan A. Salem Now with Taif University, Dept. of Mechanical Engineering, Taif, SA