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A Hybrid Efficient PV-Battery Powered LED Lighting Scheme

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Abstract— As we all know now a day's developing countries across Asia and Africa are hit with the serious energy crisis. So To fulfill the power demand people started looking towards renewable sources of energy such as solar and wind energy. In this paper fully controlled, flexible and self-adjusting LED lighting PV-Battery powered scheme using a pulse-width modulation (PWM) switching and controlled by a dual-loop error driven, time de-scaled, WM proportional-integral-derivative (WM-PID) control scheme for the PV-battery interfaced to the LED load. It decreases the amplitude of transient voltage and minimize inrush current for balancing common DC bus to the LED load. The new adjustable controller uses a directed dual-loop error-driven, error-time descaled controller for the PWM switching along with MOSFET/IGBT switches. The dual-action regulator uses error driven weighted modified (WM-PID) proportional-integral-derivative controller with quick response auxiliary derivative loops to achieve efficient control action.

Keywords*-LED lighting scheme, PV system, Error driven descaled controller, Battery charging, PID control*

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I. INTRODUCTION

As Renewable energy resources are clean and environmentally friendly. They can provide many immediate environmental benefits by avoiding the emission of greenhouse gases and can help conserve fossil resources as electricity supply for future generations. Therefore, newer renewable electricity sources are targeted to grow massively by 2022, including a more than doubling of India's largest wind power capacity and an almost 15fold increase in solar power generation.

PV-residential, commercial and industrial parks/farms for energy utilization used in village/resort/smart building and their efficiently illumination systems are gaining full momentum due to energy policies and carbon emission guidelines supported by government rebates and economic incentives. A high-performance stand-alone solar LED lighting systems was developed for this reason. Therefore, the constant current driving is used widely in commercial products instead of constant voltage driver. Rapid developments in LED lighting systems have made this device a potential candidate for PV powered efficient LED lighting systems.

This paper presents a PV array interfaced with Lithium Ion battery which is further given to LED lighting system with a boost converter. This study aims to design PV powered battery-charging stations for LED lightening using a modulated common DC bus interface and a dual loop error driven WM-PID control method. Further details of the designed system are given in the second chapter. The modeling of this system is done in MATLAB and simulated for different SOC and study conditions.

II. PV-BATTERY POWERED LED TEST SYSTEM

The equivalent circuit shown below. This model consists of a current source and a diode connected in parallel.

The series resistance (*Rs*) represents the internal losses caused by the current flow of the solar cell. Connected parallel diodes resistance (*Rsh*) represents the leakage current taken place from the losses occurring in soil.

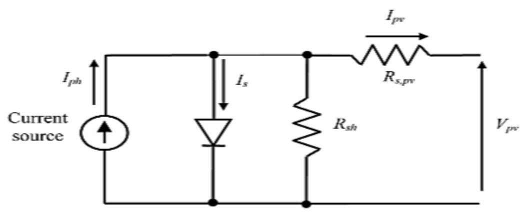


Figure (1): Equivalent circuit of Solar Cell

ISSN: 2454-4248
474 – 478

Fig 2. Shows the PV array and Li-Ion battery powered Light Emitting Diode (LED) lighting scheme with a boost converter. Both filtering stabilize the DC common bus under SOC variations, and conditions for power LED loads is provided by this scheme. This paper presents a scheme to achieve efficient energy usage, damping voltage transients and limited raid currents. In addition, a boost converter for output load voltage regulation is demonstrated.

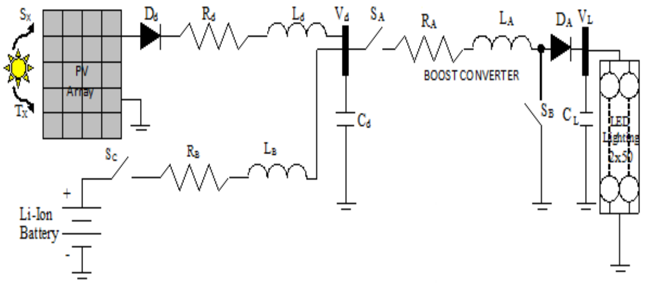


Figure 2. Test system PV and battery powered LED lighting system.

The proposed scheme shown in Figure 1 utilizes a SPWM with two supplementary (S_A and S_B) and one alone (S_C) MOSFET/IGBT switches. This control switching signals are generated by dual loop regulator and PID controllers using the bus voltages and currents for efficiency of the lighting system. The hybrid system switching GPFC scheme is capable in decreasing unstable voltage, steep current conditions,so stabilizes DC-bus voltage during load, quick charging scheme, stabilize array of PV solar S_X, and transient error. The load is selected as a LED module lighting which consists of two parallel and 50 pcs series power LED cells.

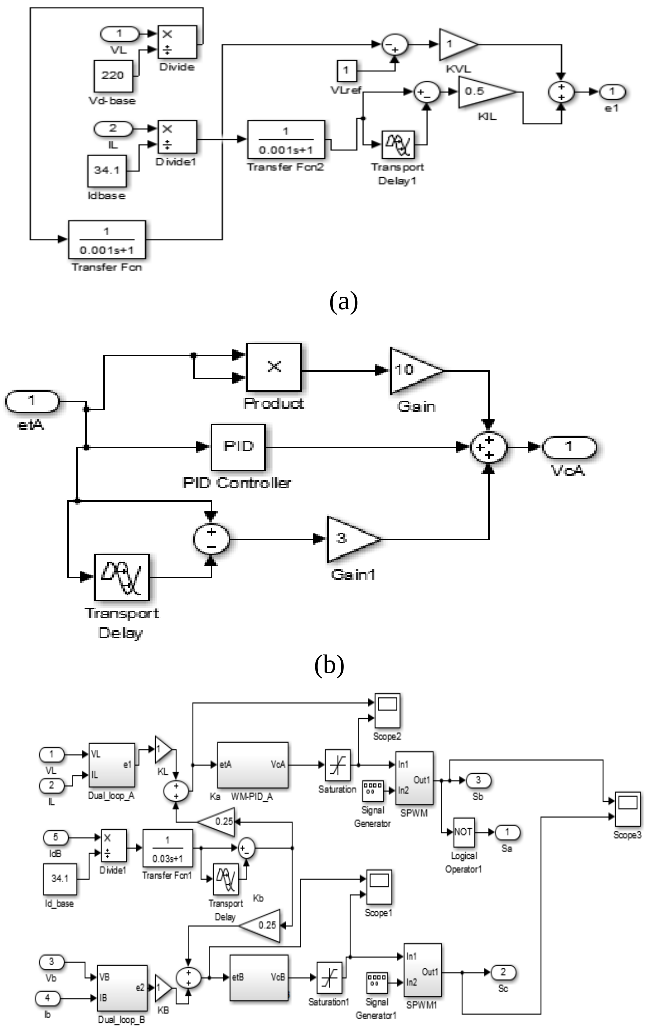
A. *Dual Loop Regulator Control Scheme*

The novel efficient PV array and Li-Ion battery powered LED lighting system with a boost converter controlled by dual loop regulator control scheme is proposed. In this study, dual loop regulation control scheme with error-driven WM-PID (proportional, integral, derivative) controller is proposed as shown in Fig. 3.The pulsing sequence to MOSFET/IGBT is been utilized by two dual loop error driven regulators. A dual supplementary switching pulse(Sa & Sb) and a dc/dc boost converter is used to design a green plug filter compensation scheme.

The two error signals e_1 and e_2 is used by the two dual loop error driven time-descaled regulators. Even though the error signals for V and I are not same for both the regulator, the error signal is described in Eq. (1).

$$e_{1,2}(t) = K_V e_1 \qquad (1)$$

The error signals are obtained from both dual loop regulator which is enclosed in to the controller as shown in third figure. The two disparate PWM signals is obtained from the two error signals e_1 and e_2. These two e_1 and e_2 signals are combined with an error-driven weighted modified PID (proportional, integral, derivative) controller. Among both error signals, first error signals (Sc) runs the battery circuits for input common bus stabilization; and the second error signal synchronize (Sa= $\bar{S}$, and runs the converter switch (MOSFET or IGBT).



(a)

(b)

(c)

Figure (3): Multi loop error driven dual- loop regulator model (a), WM-PID controller model (b), Dual loop, dual regulator hybrid controller model (c).

B. *Components of the LED Lighting System*

The PV and battery back-up powered LED lighting scheme consist of four main components: Photovoltaic array, Li- Ion Battery module, power LED load unit and the Boost dc-dc converter. More details of Matlab/Simulink modeling of these components are given in this chapter.

B.1. PV Array Modeling

The value of temperature and irradiation can not be defined from the fundamental steady state V-I characteristic eq. for PV cell because it does not include all the parameters. To increase voltage and current of PV array, the PV cells are to be connected in series or parallel respectively. Also, temperature and solar radiation variation parameters were added. This can be shown by Eq 2.

ISSN: 2454-4248
474 – 478

$$V_{PV} = \frac{N_S.n.k.T}{q} \ln\left[\frac{(I_{SC} + K_I(T - T_{ref})).G + I_0 - I_{PV} + N_P}{I_0.N_P}\right] - \frac{N_S}{N_P} R_s.I_{PV} \quad (2)$$

This obtained volt-ampere equation for the photovoltaic module was applied by the first author in Matlab/Simulink in the previous studies as shown in Figure 3. The simulations are realized using this PV model. The modeling of PV array is done to observe and try at different Sx, Tx solar insulation and temperature change [2, 6].

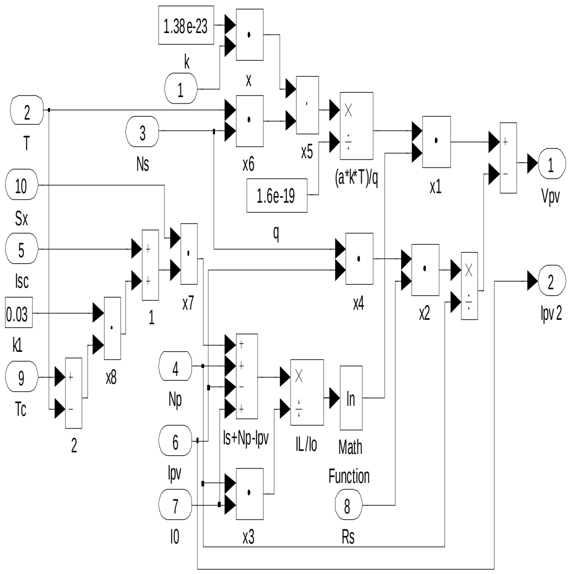


Figure 4. PV Array Matlab/Simulink functional model.

B.2. Power LED Unit Modeling

The diodes I-V characteristic does not behave as a linear load. The electrical working of LED acts as a -ve temp. resistance. Thus, it is required to use real LED load models instead of linear loads. The used power LED Matlab/Simulink functional model is given in Figure 5. For this LED model, the I-V curves of a LED lamp at a different junction temperature are used to derivate a quadratic function which is given in Equation 3 [4, 8].

$$I_L = a_0 + V_L a_1 + {V_L}^2 a_2 \qquad (3)$$

The necessary coefficients for 50W LED luminaries and 50 pcs series power LED is added to the Matlab/Simulink for unit LED model. Connecting two series unit LED model, the necessary load power is obtained for the use in simulations.

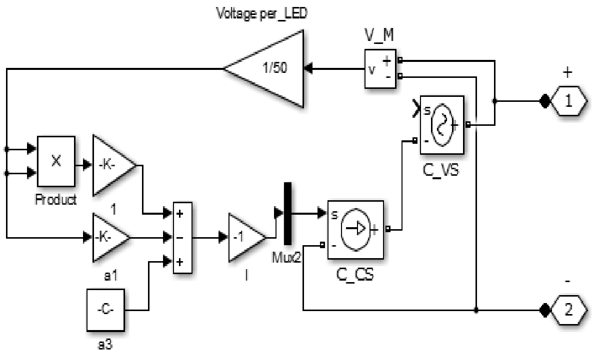


Figure 5. Matlab/Simulink model for 50 fixtures LED

III. SIMULATION AND RESULTS

The PV array and Li-Ion battery powered LED lighting system with a boost converter is prepared in MATLAB as given in Figure 6. This model is designed with a PV module and Li-Ion battery block and a boost converter to start LED loads. The synchronous switching signals (S_a and S_b) are generated using the measured load current and voltage values and converter diode current. The other switching signal (S_c) is generated using the measured battery current and voltage values and converter diode current.

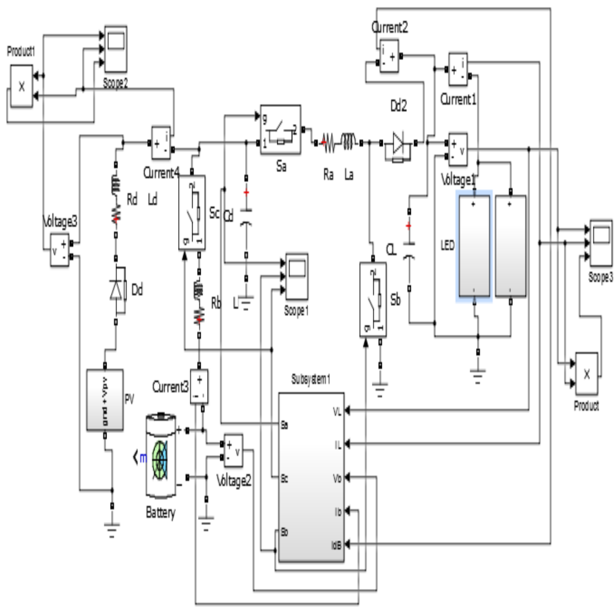


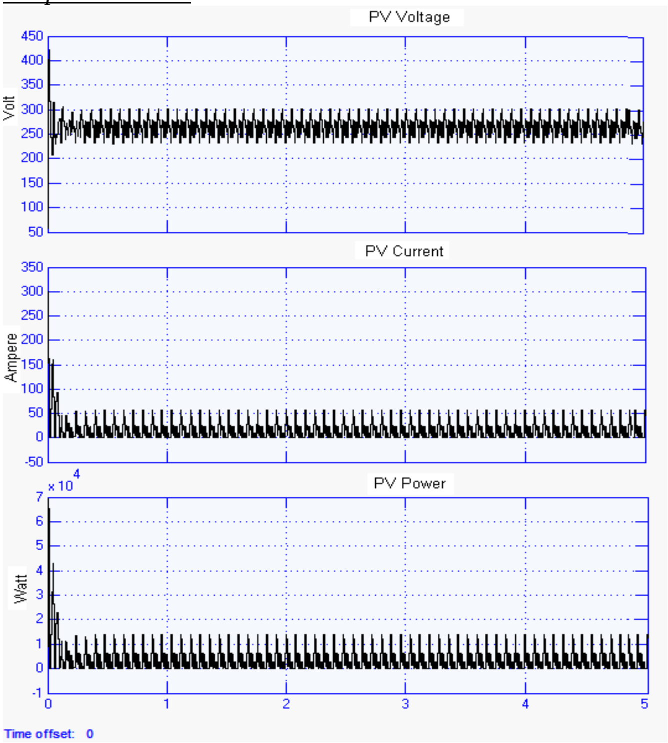
Figure 6: The general Matlab/Simulink model of PV array and Li-Ion battery powered LED lighting system.

Figure 7(a) and 8(a) shows Matlab-Simulink digital simulation results of PV voltage, current and power on LED load for 90% SOC and 50% SOC respectively and Figure 7(b) and 8(b) shows output voltage, current and power on LED load for 90% SOC and 50% SOC respectively. The high SOC ratio decreases ripples on PV voltage, current and power values because of sufficient energy supply.

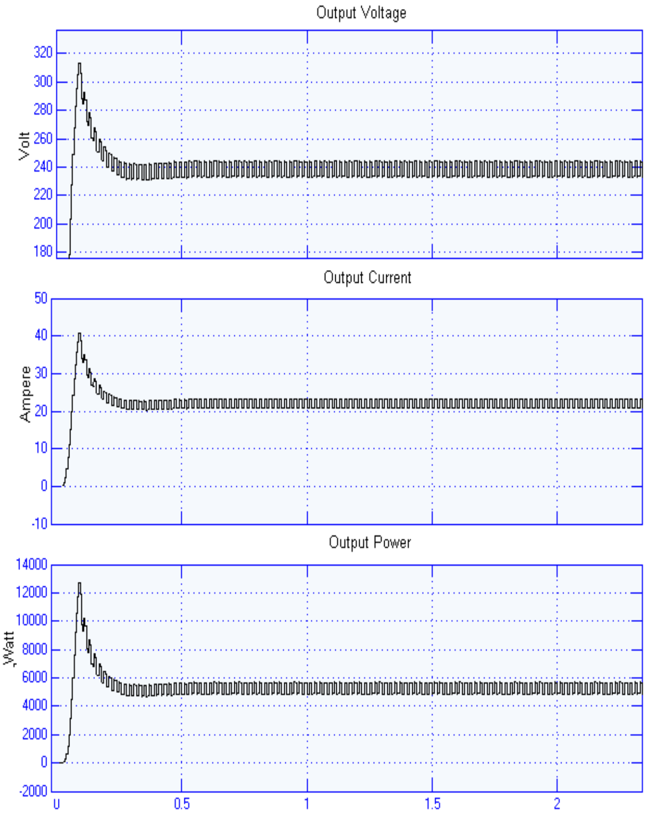
ISSN: 2454-4248
474 – 478

Fig. 9(a) shows simulation results of V, I and power for PV and Fig. 9(b) shows output voltage, current and power on LED load when PID control scheme is not used and without interfacing battery.

Graphical results

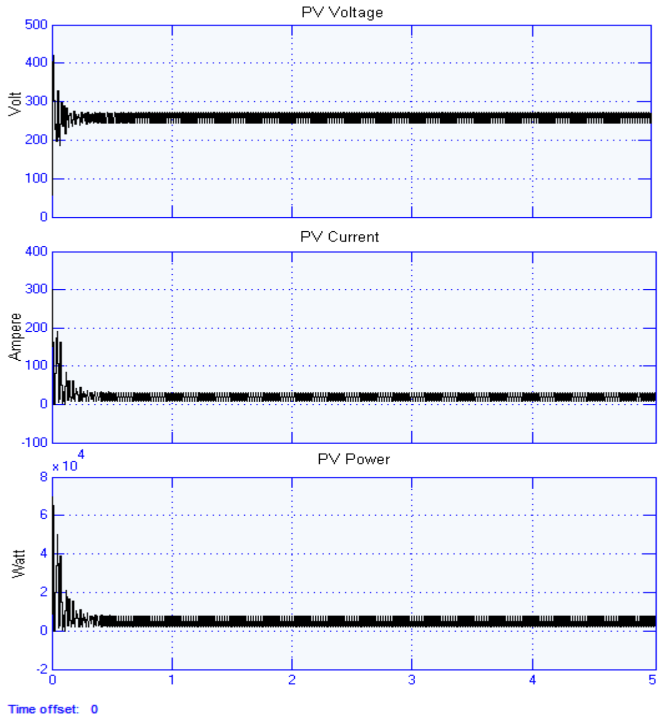


(a)

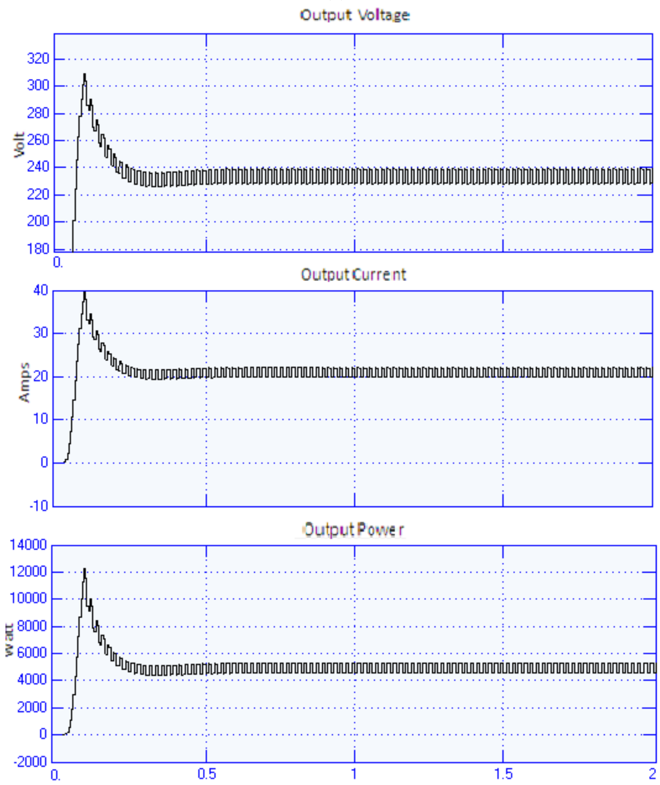


(b)

Figure 7. (a) PV voltage, current and power, (b) output voltage current and power simulation results for SOC 90%.

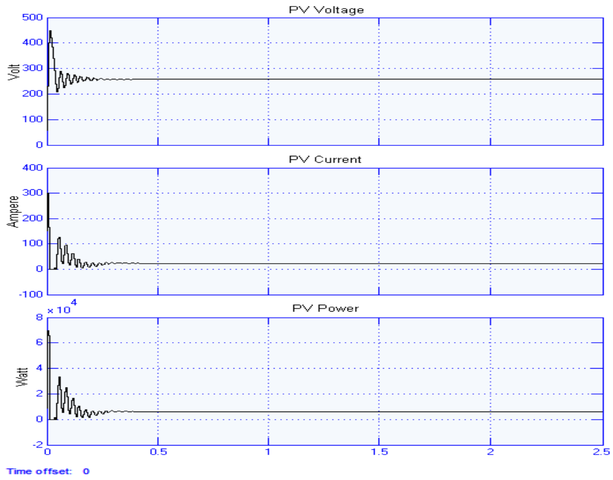


(a)

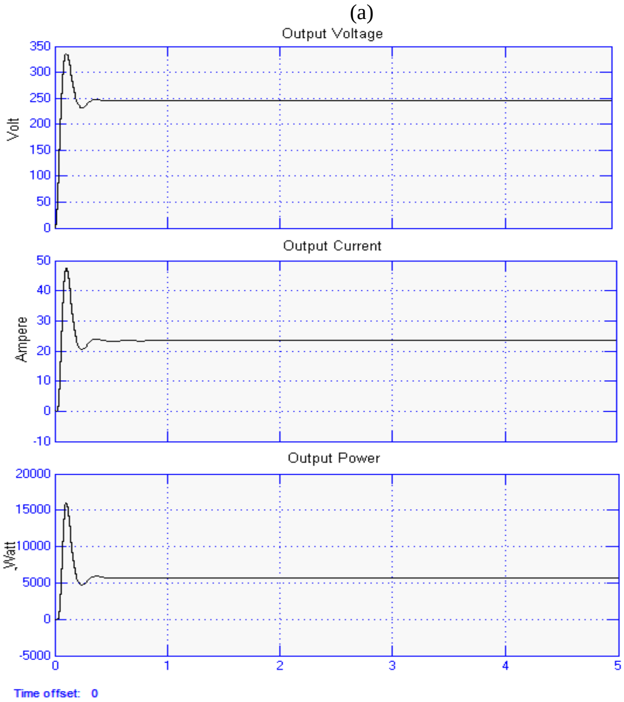


(b)

Figure 8. (a) PV voltage, current and power, (b) output voltage current and power simulation results for SOC 50%.



(a)



(b)

Figure 9. (a) PV voltage, current and power, (b) output voltage current and power simulation results without battery and PID controller

IV. CONCLUSION

This paper presents PV array-Li-Ion battery powered light emitting diode (LED) lighting scheme with a boost converter. This scheme was controlled by a dual-loop error driven, time descaled WM-PID controller. The models of PV array and Li-Ion battery powered LED lighting system were simulated for different SOC and different PV insolation and temperature conditions in Matlab/Simulink. Voltage, current and power waveforms were compared. The digital simulation results stabilized DC bus voltage reduced current inrush conditions for load connected. The proposed scheme of PV- Battery can be extended to Micro feul DC- AC interface as well as Hydrogen Production an led Electric utility smart grid Li-Ion Battery and Fuel cell Battery based PV solar Park utility as well as commercial back up storage storage systems. The extended DC- AC schemes can be be commercialized for resort areas/ isolated communities/ large malls and Airport Lightning schemes. The green plug do and FACTS AC side Stabilization SFC developed by the Third Author can be utilized to reduce ripple content and improve energy efficiency and power quality.

REFERENCES

[1] A. R. Patel, et al. "Modeling and simulation of photovoltaic based LED lighting system" *World Academy of Science, Engineering and Technology* vol.73, pp.647-651, 2011,

[2] A. M. Sharaf, M. E. Sahin, “A Flexible PV-Powered Battery-Charging Scheme for Electric Vehicles”, *IETE Technical Review*, 2016.

[3] M. E. Sahin¸ A. M. Sharaf, and H.I. Okumus, “A novel filter compensation scheme for single phase-self-excited induction generator micro wind generation system”, *Sci. Res. Essays*, Vol.7, pp. 3058-72, 2012.

[4] B. J. Huang, P.C. Hsu, M. S. Wu, C. W. Tang, “Study of system dynamics model and control of a high-power LED lighting luminaire”, *Energy*, vol. 32, pp.2187–2198, 2007.

[5] Mustafa Ergin Şahin ,Adel Mahmoud Sharaf “A novel efficient PV-Battery powered LED lighting scheme”, *IEEE Transactions* , ICSG Istanbul 2017.

[6] M. E. Sahin and H. I. Okumus, “Physical Structure, Electrical Design, Mathematical Modeling and Simulation of Solar Cells and Modules” *Turkish Journal of Electromechanics and Energy*, Vol.1, pp. 1-8, 2016.

[7] M. E. Ropp, and S. Gonzalez, "Development of a MATLAB/Simulink model of a single-phase grid-connected photovoltaic system", *IEEE Transactions on Energy Conversion*, vol. 24.1, pp. 195-202, 2009.

[8] B. J. Huang, et al., "Direct battery-driven solar LED lighting using constant-power control", *Solar Energy*, vol. 86.11, pp.3250-3259, 2012.

[9] L. Maharjan, S. Inoue, H. Akagi, and J. Asakura, “State-of charge balancing control of a battery energy storage system based on a cascade PWM converter”, IEEE Trans. Power Electron., Vol.24, pp.1628-36, 2009.

[10] Y. A. O. Liangzhong, et al. "Challenges and progresses of energy storage technology and its application in power systems", *Journal of Modern Power Systems and Clean Energy*, vol. 4.4, pp. 519-528, 2016.

[11] MathWorks (2016), Implement generic battery model-Simulink, [online], Available: https://www.mathworks.com.

Appendix

Designed DC System Parameters

PV Array Parameters	
PV voltage (DC)	280 V
PV power	10 kW
R_d, L_d	0.1 Ω, 2-3 mH
Battery Parameters	
Battery model	Lithium–Ion
Battery voltage	240 V (nominal)
Battery rated capacity	240 Ah
R_b, L_b	0.1 Ω, 2-3 mH
Line and Boost Converter Parameters	
S_a, S_b, S_c	MOSFET switches
C_d, C_L	6500 µF, 10000µF
R_a, L_a	0.5 Ω, 150 mH
LED Lights Load Parameters	
Number of LEDs	50x2=100 pcs
Each LED power	50 W
LED load power	5 kW
a_0, a_1, a_2	0.2037, 0.7955, 0.6408
WM-PID Controller Parameters	
K_P, K_I, K_d	100, 30, 15
K_e, K_r	10, 3
Switching frequency(f_{sw})	1750 Hz