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*Dedicated to
Our parents, brothers, sisters, teachers, and
friends for their love, encouragement, and
endless support.
We give all thanks and gratitude to our
beloved wife and to our daughters and sons
wishing from God to protect them.*

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ
"يَرْفَعُ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ"
صدق الله العظيم
المجادلة/ 11

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Abstract

Recently, the permanent growth of the energy demand and the rapid depletion of the conventional power sources have attracted the research interests of the authors toward the renewable energy sources, especially the photovoltaic (PV) energy as alternative sources of energy. The PV energy can be utilized only during the daylight. Therefore, the integration of the PV energy and the energy storage system as the battery supercapacitor can attenuate their individual fluctuations, increase the overall output power, and generate more reliable power with higher quality to the electrical loads in the rural areas. The aim of this book is to study and design the performance analysis of the PV stand-alone systems with energy storage systems as follows:

- This book investigates dynamic modeling, simulation, and control strategy of the PV stand-alone system during variation of the environmental conditions. Moreover, the effectiveness of the implemented maximum power point tracking (MPPT) techniques and the employed control strategy will be evaluated during variations of the solar irradiance and the cell temperature. The simulation results are based on the reliability of the MPPT techniques applied in extracting the maximum power from the PV system during the rapid variation of the environmental conditions. Furthermore, it introduces a review of two MPPT techniques that are implemented in the PV systems, namely, the perturb and observe (P&O) MPPT technique and the incremental conductance (InCond) MPPT technique. The two MPPT techniques were simulated by the MATLAB/Simulink, and the results response of the PV array from voltage, current, and power are compared to the effect of solar irradiation and temperature change.
- Then, the proposed PV stand-alone system is utilized to supply the demanded power of variable loads. The PV array is connected to battery energy storage (BES) through the DC bus in order to supply the demanded power of the variable loads. Moreover, the power flow control strategy is proposed to feed the demanded power of the variable loads. The BES can act as a buffer store to eliminate the mismatch between PV power and load demand. Furthermore, the BES helps to improve the performance of the system through the control used in the

process of charge and discharge to manage the sudden load changes and helps to maintain a stable voltage level on the load and PV terminals.

- Improving the performance of the PV stand-alone system by leveraging the properties of the battery-supercapacitor hybrid energy storage system (BS-HESS), this book proposes an efficient control strategy to enhance the BS-HESS capable of the PV stand-alone system.
- The PV panels are not an ideal source for battery charging; the output is unreliable and heavily dependent on weather conditions. Therefore, an optimum charge/discharge cycle cannot be guaranteed, resulting in a low battery state of charge (SOC%). Low battery SOC leads to sulfation and stratification, both of which shorten battery life. A control strategy is essential for the BS-HESS to optimize the energy utilization and energy sustainability to a maximum extent as it is the algorithm which manages the power flow of the battery supercapacitor.
- Performance analysis of the PV stand-alone system with BS-HESS during the high fluctuation solar irradiation and variable load power for rural household load profile.

Contents

1	Introduction	1
1.1	Background	1
1.2	Photovoltaic Power Generation	2
1.2.1	Worldwide Annual Growth of PV Generation	2
1.2.2	Photovoltaic Power Generation in Egypt	3
1.3	Basics of Solar Cell	4
1.4	Types of PV with Storage Installations	5
1.4.1	Grid-Connected PV System	5
1.4.2	Grid-Tied System with Battery Backup	6
1.4.3	Off-Grid System	7
1.4.4	PV-Hybrid Systems	8
1.5	Energy Storage System	9
1.6	Book Objectives	9
1.7	Book Organization	10
2	Literature Survey	11
2.1	Introduction	11
2.2	Why Use a Battery Energy Storage in PV Systems?	12
2.3	BES Types and Classifications	12
2.3.1	Primary BES	13
2.3.2	Secondary BES	13
2.4	Battery Energy Storage Characteristics	13
2.4.1	Battery Energy Storage Charging	14
2.4.2	Battery Energy Storage Discharging	14
2.4.3	Compare the Characteristics of Some Types of BESs	16
2.5	Lead-Acid Battery Energy Storage	17
2.6	Calculating Battery Size for a PV System	18
2.6.1	Select the Appropriate Voltage	18
2.6.2	Define Maximum Depths of Discharge	19
2.6.3	Calculate the Battery Capacity	19
2.7	The Supercapacitor Energy Storage System in PV System	19

2.8	Literature Survey of Previous Works	23
2.8.1	Review of Related Researches About PV Modeling	24
2.8.2	Review of Related Researches About MPPT of PV System	25
2.8.3	Review of Related Researches About Half-Bridge Bidirectional DC/DC Converter.	25
2.8.4	Review of Related Researches About a Stand-Alone PV System with HESS.	26
2.9	Summary	26
3	Modeling of Maximum Power Point Tracking for Stand-Alone PV Systems	27
3.1	Introduction	27
3.2	Principle of PV Conversion Systems	28
3.3	The Main Components of Stand-Alone PV Systems.	29
3.3.1	The Equivalent Circuit of the PV Model	30
3.3.2	Calculation the PV Boost DC/DC Converter.	31
3.4	MPPT Techniques of Stand-Alone PV System	34
3.4.1	Perturb and Observe MPPT Technique	35
3.4.2	Incremental Conductance MPPT Technique	41
3.4.3	The Comparison Between P&O and InCond MPPT Methods	46
3.5	Summary	48
4	Improving the Resiliency of a PV Stand-Alone with Energy Storage	49
4.1	Introduction	49
4.2	Structure and Modeling a PV Stand-Alone with Battery Energy Storage	49
4.2.1	Mathematical Modeling of the PV Array Under Study	50
4.2.2	DC/DC Boost Converter	52
4.2.3	Single-Phase DC/AC Inverter	52
4.2.4	Filter Design.	55
4.2.5	Modeling of Battery Energy Storage.	58
4.2.6	Half-Bridge Bidirectional DC/DC Buck/Boost Converter	60
4.3	Simulation Results and Discussion of Stand-Alone PV System with BES	63
4.3.1	Comparison Between PV System with and Without BES Under Constant Irradiation	64
4.3.2	Simulation Results PV System with BES at Variable Irradiation.	68
4.3.3	Voltage and Current Harmonic Analysis	71
4.4	Summary	74

5	The Performance Analysis of a PV System with Battery-Supercapacitor Hybrid Energy Storage System	75
5.1	Introduction	75
5.2	Structure and Simulation of Stand-Alone PV Systems with BS-HESS	76
5.2.1	Supercapacitor Model	79
5.2.2	Control Circuit of Bidirectional DC/DC Buck/Boost Converter	81
5.3	Control Strategies of HESS	81
5.3.1	Filtration-Based Controller Strategy	82
5.3.2	Intelligent Control Strategy Based on LPF and FLC.....	83
5.4	Simulation Results for Stand-Alone PV Systems with BS-HESS	86
5.5	Summary	99
6	Experimental Work	101
6.1	Introduction	101
6.2	Experimental Setup of Off-Grid PV System	101
6.2.1	Elements of the Experimental Setup	102
6.3	Experimental Results and Discussion	109
6.3.1	Model 1: Experimental Results of the System Without Battery	110
6.3.2	Model2: Experimental Results of the System with Battery	111
6.3.3	Model 3: Experimental Results of the System Connected to Battery and Changing Solar Irradiation.	113
7	Conclusions and Future Work	119
7.1	Conclusions	119
7.2	Suggestions for Future Work	121
	Appendices	123
	References	127
	Index	133

List of Figures

Fig. 1.1	Global PV generation capacity and annual additions, 2007–2017 [12]	3
Fig. 1.2	PV module constructions and its circuit [14]. (a) Construction of PV module. (b) Circuit of PV module.....	4
Fig. 1.3	Block diagram of grid-connected PV system [14].....	5
Fig. 1.4	Block diagram of grid-tied system with battery backup [19]	6
Fig. 1.5	Block diagram of stand-alone PV system with battery storage [14].....	7
Fig. 1.6	Block diagram of photovoltaic hybrid system [14]	8
Fig. 2.1	Chemical reaction when a battery is being discharged [33]	18
Fig. 2.2	Charge and discharge characteristic of lead-acid BES voltage per cell [31]	18
Fig. 2.3	The illustrative topology of a SC, depicting the electrical double layers at each electrode/electrolyte interface [40].....	20
Fig. 2.4	Supercapacitor modules from Maxwell Technologies, Appendix A	21
Fig. 2.5	The capacitance and the ESR as temperature-dependent characteristics. Appendix A	22
Fig. 2.6	Block diagram of stand-alone PV system with BS-HESS.....	24
Fig. 3.1	Photocurrent generation principle of the PV cell [67].....	28
Fig. 3.2	PV cell, PV module, and PV array [67].....	28
Fig. 3.3	Simulink block diagram of the stand-alone PV system with DC/DC converter	29
Fig. 3.4	Equivalent circuit of the PV cell	30
Fig. 3.5	Configuration of the PV array	31
Fig. 3.6	Characteristics of a typical PV array during variation of solar irradiance and temperature. (a) Current-voltage (I-V) and power-voltage (P-V) characteristics of PV array under variable solar irradiance. (b) Current-voltage (I-V)	

and power-voltage (P-V) characteristics of PV array under variable temperature..... 32

Fig. 3.7 Basic configuration of the DC/DC boost converter 33

Fig. 3.8 Switching modes of the DC/DC boost converter.
 (a) Mode 1: when the switch (Q1) is turned on.
 (b) Mode 2: when the switch (Q1) is turned off 33

Fig. 3.9 The basic principle of MPPT in PV conversion systems..... 36

Fig. 3.10 Flow chart of the P&O MPPT technique..... 37

Fig. 3.11 The solar irradiation and cell temperature profile..... 38

Fig. 3.12 MATLAB/Simulink model of the P&O MPPT technique..... 38

Fig. 3.13 The output of PV voltage, current, and power versus time curve without MPPT technique 39

Fig. 3.14 The output of PV voltage, current, and power versus time curve with P&O MPPT technique 40

Fig. 3.15 The output DC/DC boost converter – voltage, current, and power with P&O MPPT technique..... 41

Fig. 3.16 The basic concept of InCond MPPT technique 42

Fig. 3.17 Flow chart of InCond MPPT technique 43

Fig. 3.18 MATLAB/Simulink model of the InCond MPPT technique 45

Fig. 3.19 Output of PV voltage, current, and power versus time curve with InCond MPPT technique..... 45

Fig. 3.20 The output DC/DC boost converter – voltage, current, and power with InCond MPPT technique..... 46

Fig. 3.21 PV array voltage comparison between P&O and InCond MPPT techniques 47

Fig. 3.22 PV array current comparison between P&O and InCond MPPT techniques 47

Fig. 3.23 PV array power comparison between P&O and InCond MPPT techniques 48

Fig. 4.1 Simplified diagram of the stand-alone photoelectric system with energy storage 50

Fig. 4.2 The electrical model of the PV array 50

Fig. 4.3 MATLAB/Simulink model of the PV array 51

Fig. 4.4 The PV array with the DC/DC boost converter 52

Fig. 4.5 (a) Full-bridge converter; (b) S1 and S2 closed; (c) S3 and S4 closed; (d) S1 and S3 closed; (e) S2 and S4 closed 53

Fig. 4.6 The dynamic error-driven PI controller for the DC-AC inverter 55

Fig. 4.7 LCL filter and components 56

Fig. 4.8 LCL filter with passive damping resistance [79] 56

Fig. 4.9 The equivalent circuit of battery [81]..... 57

Fig. 4.10 Discharge characteristics of a lead-acid battery.
 (a) Nominal current discharge characteristic at (2A).
 (b) Discharge characteristic at diverse current values 59

Fig. 4.11 Circuit diagram of half-bridge bidirectional DC/DC converter 60

Fig. 4.12 (a) Buck converter circuit and (b) boost converter circuit..... 61

Fig. 4.13 Boost mode. (a) Interval 1, (b) Interval 2 62

Fig. 4.14 Buck mode. (a) Interval 1, (b) Interval 2 62

Fig. 4.15 Simulink model of a stand-alone PV system with a BES 63

Fig. 4.16 Load profile 64

Fig. 4.17 The current response of PV system. (a) PV output current and (b) AC RMS load current 65

Fig. 4.18 The voltage response of PV system. (a) PV output voltage, (b) DC voltage, and (c) AC RMS load voltage 66

Fig. 4.19 The power response of PV system, (a) PV generated power, and (b) load active power..... 67

Fig. 4.20 The BES response. (a) Battery state of charge (SOC %), (b) battery current, and (c) battery voltage 68

Fig. 4.21 Solar irradiation profile 69

Fig. 4.22 Simulation results of the PV system with BES. (a) PV output current and (b) AC load current 69

Fig. 4.23 Simulation results of the system with BES. (a) The PV output voltage and boost output DC voltage, (b) AC load voltage..... 70

Fig. 4.24 Simulation results of the PV system without BES for the PV generated power, load power, and battery power..... 70

Fig. 4.25 BES response (a) SOC %, (b) battery current, and (c) battery voltage 71

Fig. 4.26 Harmonic analysis of AC load current and AC load voltage before and after using LCL filter. (a) THD of the AC voltage before using LCL filter. (b) THD of the AC current before using LCL filter. (c) THD of the AC voltage after using LCL filter. (d) THD of the AC current after using LCL filter. (e) Harmonic spectrum of AC current after using LCL filter 72

Fig. 5.1 Simplified diagram of the stand-alone PV system with energy storage..... 77

Fig. 5.2 Ragone chart showing the power density and energy density of different storages [89]. (Source: US Defence Logistics Agency) 77

Fig. 5.3 Two different models of proposed system. (a) Stand-alone PV system with battery-only storage. (b) Stand-alone PV system with BS-HESS system 78

Fig. 5.4 Supercapacitor equivalent circuit model [92] 79

Fig. 5.5 Time intervals of charge and self-discharge characteristic for SC..... 80

Fig. 5.6 Circuit diagram of half-bridge bidirectional DC/DC converter 81

Fig. 5.7 Control circuit of bidirectional DC/DC converter 82

Fig. 5.8 Structures of the filtration-based controller based on FBC..... 83

Fig. 5.9	Structures of the intelligent control strategy based on LPF and FLC	83
Fig. 5.10	Inputs and output membership functions for FLC. (a) Input 1: P_{LF} . (b) Input 2: SOC_{SC} . (c) Output MFs.....	85
Fig. 5.11	Solar irradiation profile	86
Fig. 5.12	Profile of load demand.....	86
Fig. 5.13	Output power from PV array	87
Fig. 5.14	Power mismatch between PV power generation and load demand power (dP)	87
Fig. 5.15	Battery current, voltage, power, and SOC (%) for Model 1. (a) Battery current (A) for Model 1. (b) Battery voltage (V) for Model 1. (c) Battery power (W) For Model 1. (d) Battery SOC (%) for Model 1	88
Fig. 5.16	Battery current, voltage, power, and SOC (%) for Model 2. (a) Battery current (A) for Model 2. (b) Battery voltage (V) for Model 2. (c) Battery power (W) For Model 2. (d) Battery SOC (%) for Model 2.....	90
Fig. 5.17	Operating curves of the SC for Model 2. (a) SC current (A) for Model 2. (b) SC voltage (V) for Model 2. (c) SC power (W) For Model 2. (d) SC-SOC (%) for Model 2	92
Fig. 5.18	Battery current, voltage, power, and SOC (%) for Model 3. (a) Battery current (A) for Model 3. (b) Battery voltage (V) for Model 3. (c) Battery power (W) For Model 3. (d) Battery SOC (%) for Model 3	94
Fig. 5.19	SC current, voltage, power, and SOC (%) for Model 3. (a) SC current (A) for Model 3. (b) SC voltage (V) for Model 3. (c) SC power (W) For Model 3. (d) SC- SOC (%) for Model 3	96
Fig. 5.20	Comparison of the battery current of all the models.....	98
Fig. 5.21	Comparison of the battery voltage of all the models	98
Fig. 5.22	Comparison of the battery power of all the models	99
Fig. 6.1	Experimental setup for stand-alone PV system with AC load	102
Fig. 6.2	Solar modules simulation.....	103
Fig. 6.3	Experimental work for characteristic of PV array (one series and three parallel strings).....	104
Fig. 6.4	I-V curves of PV array with different solar irradiations	104
Fig. 6.5	P-V curves of PV array with different solar irradiations	105
Fig. 6.6	Solar charge controller MPPT.....	105
Fig. 6.7	Off-grid inverter	106
Fig. 6.8	Lead-acid battery	107
Fig. 6.9	Load unit – 500 W	107
Fig. 6.10	Analog-digital multimeter.....	108
Fig. 6.11	DC lamp board.....	109