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Optimal Planning and Multicriteria Decision-Making Analysis of Local Energy Production Systems Considering Stability and Power Quality Enrichment

PhD Dissertation Booklet

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1. Introduction

With the rocket increase in energy demand around the globe, the incredible population growth, urbanization, industrial progress, water shortage and lack of electricity access crises, and the global warming dilemma, the devolution towards sustainable energy systems through the appropriate integration of renewable energy sources (RESs) has grown to become a must. Despite the great benefits of RESs, their integration into local energy projects is confronting different challenges due to their high initial capital cost, limiting their actual implementation and intermittency nature which could cause different stability problems. The intermittency nature of RESs and their stability issues can be tackled by integrating proper and robustly controlled energy storage systems (ESSs), while the cost concern can be handled by deciding the optimal design/layout of the energy system. This integration between RESs and ESSs is usually known as local energy production system (LEPSs), hybrid renewable energy systems, or microgrids as displayed in Fig. 1.

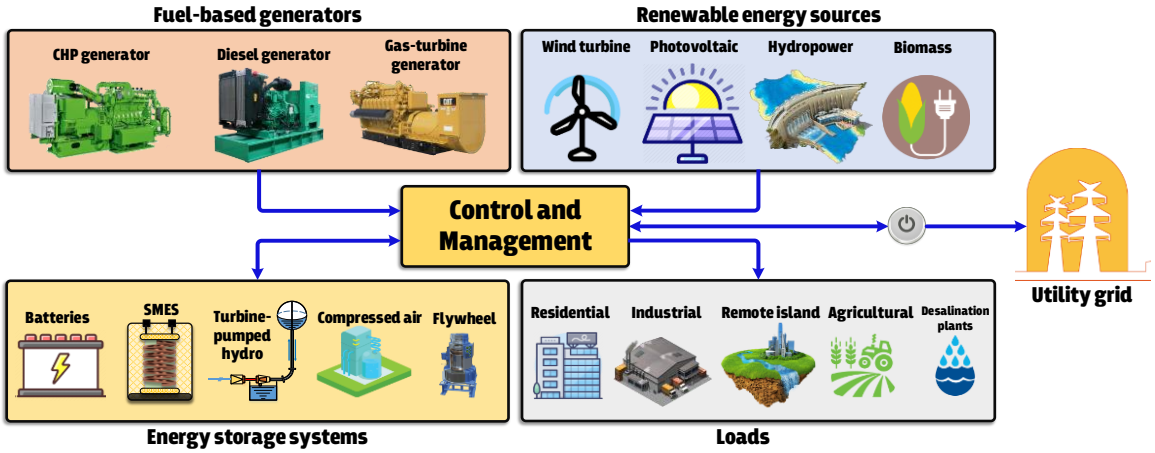

Fig. 1 Schematic diagram of a typical LEPS

The design optimization of such energy systems attracted the attention of many researchers since it is considered a multifaceted task, challenging, and requires solutions that encompass various matters in the design process. Selecting an accurate design based only on a single performing aspect could be a significant misstep since a multiplicity of influential aspects, parameters, constraints, and criteria should be considered during the design procedure. Thus, the design of such LEPSs should be realized as a multi-dimensional problem. Also, the accessibility and arrangement of RESs, demand information, energy policies, and sustainability objectives should be carefully identified and assessed. Also, selecting the optimal energy solution and assessing its reliability, stability, and power quality are essential to

realizing how the system would act on different climatic and load instabilities during the year. The substance which could take the lead to create a thorough and vigorous design framework.

Establishing LEPSs is encircled by different challenges which require distinct phases of feasibility analysis and investigations. Picking up an appropriate location for implementing these energy systems is considered a crucial factor that could cause large deficits and project feasibility if it has not a sufficient potential of renewable energy resources (RERs). Also, the inappropriate choice of the project site has significant consequences associated with visual interference, sound pollution, and environmental devastation [1]. Besides, selecting the best configuration to supply the load constantly with the lowest costs is considered another vital challenge that should be decided accurately using optimization tools or algorithms. The main reason that makes the design more challenging is that it involves several contradictory criteria and alternatives with a large number of influential parameters; hence, the design problem should be considered as multiple objective problems that can be handled by either multi-objective optimization algorithms or employing multicriteria decision-making (MCDM) approaches. The incorrect sizing of the system's components undoubtedly causes infeasible performance in both expenditures and functioning aspects. Besides, the system components' non-linearity, the existence of RERs, and load uncertainty greatly influence the LESPs performances [2]. Another challenge concerns the future performance of the designed LEPS and its behaviour against any expected change in any influential design parameters (e.g., load growth, meteorological variations, and the economic parameters variation). Moreover, preserving LEPSs stability is also considered one of the vital challenges that face the operation of any RESs-based energy system. The term stability implies to the energy system capability to accomplish its proposed objective of delivering adequately supply of electrical energy to consumers efficiently with a reasonable assurance of continuity and quality. A comprehensive and accurate design optimization framework of LEPSs could facilitate the alleviating challenges; therefore, improving the potential expansion of these energy systems.

2. Literature Gaps and Research Objectives

Based on the broad survey, a large number of research works has been carried out to address the design optimization of different LEPSs using different tools/algorithms and improve the stability and power-quality of these systems by integrating ESSs based on different control approaches. Yet, these attempts have the following main observations and shortcomings:

- A high proportion of the world's population still suffers from the absence of electricity and potable water access, especially in developing countries. Consequently, spreading the investments of LEPS projects in these countries is of great importance. This matter proves the LEPSs projects' significance in achieving the UN goals.
- The different structures of LEPSs have been identified as a valuable perception over the fossil fuel-based energy production sources. Besides, the standalone LEPSs got much attention from research over the grid-connected ones since the standalone option has induced tremendous interest in sustainable energy access.
- Most of the previous studies have not offered a complete or comprehensive framework for the design optimization problem. Furthermore, the design optimization of LEPSs is regularly performed for a certain case-study in a specified site to supply a specific type of load(s), which generalizes these LEPSs practicability further complicated. Consequently, offering a comprehensive design optimization framework including MCDM analysis, dependability and sensitivity analyses, stability assessment, and power-quality appraisal could assist in achieving a better insight into the design optimization problem.
- The majority of the investigated LEPSs were in charge of supplying a single type of demand (electrical, heat or water), while a few studies have addressed the integration of cogeneration systems along with the RESs. Besides, among the few case-studies designed to energize water desalination plants, most of them have dedicated a feasibility analysis of only small-scale plants. Also, the impact of incorporating and non-existence of system's elements on the different LEPSs' manners has not been focused adequately.
- Most of researchers have assessed only the energy alternatives' techno-economic practicability while selecting the optimal solution. However, distinct aspects should be concurrently assessed in the design procedure. This weakness could destructively

impact the correct decision of design optimization problems; hence, a multi-dimensional design optimization framework should be employed.

- Studies that present the feasibility of LEPSs to supply desalination plants in Egypt as one of the countries facing a water availability crisis have not been explored adequately. Besides, the comparative analysis of multiple types ESSs has received limited attention in the literature as most of the works analyzed the LEPS performance using a single ESS. Furthermore, as far as the authors know, despite the large number of studies that utilized MCDM for the design optimization, the integration between the F-AHP and F-VIKOR methods were rarely presented in the primary literature.
- Limited investigations have addressed the integration between HOMER^{Pro}, any relevant tool, and MATLAB/Simulink to verify the technical operation, stability analysis, or optimal power quality during the year's four seasons. The matter which strengthens the design optimization framework.
- Most of the case-studies investigated the integration of RES with ESSs within the AC LEPS structure; only a few research works have addressed the DC LEPSs. Moreover, addressing the integration between SMES and wind or PV systems in the DC structure of LEPSs got less attention from researchers. Besides, the adoption of FLC for both battery and SMES in DC LEPSs has not been implemented widely alongside the application of MPPT techniques for PV and wind systems. Finally, the extreme variations of RERs and the sudden load unbalance have been rarely investigated. Most of the research work has not considered either the complete SMES model nor the appropriate control method.

Motivated from the literature review and the observed research shortcomings, this thesis introduces an advanced methodological framework for design optimization and stability enrichment of local energy production systems. The main research objectives that aim to improve the existing expertise are summarized as follows:

2.1 Proposing a methodological TEE design optimization framework of LEPSs

To select the optimal way for mixing the different energy technologies to supply different load types, a systematic techno-enviro-economic (TEE) design optimization framework for LEPSs design is proposed. The proposed model considers, simultaneously, the technical, economic, and environmental aspects of the design procedure. The matter which, to the best of authors' knowledge, has not been addressed extensively and precisely in literature which

considered only one aspect in the design procedure. The exceptionality of the presented framework is that it offers a significant target framework that can facilitate governments, policy-makers, investors, and energy developers to find out the optimal layout of LEPSs in any location. Moreover, another critical significance comes from addressing a real case-study to offer genuine solutions for existing challenges that threaten the globe, like the water shortage and lack of electricity access. The case-study which is addressed in the context of the proposed framework, aims at developing a LEPS incorporating PV units, WTs, a DsGn, a cogeneration system represented in a CHP generator, batteries, and a thermal load controller to energize a large-scale reverse osmosis desalination plant (RODP) of 850 m^3/day capacity. The proposed case-study can simultaneously supply electricity, heat, and freshwater demand for several administrative offices in an airport in Egypt.

2.2 Proposing a fuzzy MCDM model for the design optimization of LEPSs

To boost the truthfulness of the design optimization framework, a novel fuzzy MCDM model, based on merging the F-AHP and F-VIKOR techniques for the multiple objectives-based design optimization of LEPSs, is proposed. The proposed model allows the design optimization framework to evaluate the distinct energy alternatives concurrently based on a variety of key performance criteria representing distinct aspects (technical, economic, ecological, reliability, and topographical). Contrasting the aforementioned case-studies in the literature that select the optimal LEPS based on its economic behaviour only, the proposed model aims to make the sustainable energy access problem a more inclusive and multi-objective framework regarding the utilized technologies, energy alternatives, and performance criteria. The case-study adopted in the proposed model perspective aims to create a LEPS integrating PV units, WTs, and a DsGn to energize a large-scale RODP of 1000 m^3/day capacity to feed a beach resort with the freshwater needs in Baltim city, Egypt. One additional remark of this case-study is that it offers a thorough investigation and comparison between integrating two different energy storage technologies (flow batteries and turbine-pumped hydro storage) into the LEPS. Furthermore, sensitivity analysis is also accomplished for the optimal system to explore the optimal LEPS behaviour against the variation of key input parameters like cost of energy storage, load growth, and interest rate.

2.3 Proposing coordinated power management for design optimization model

Another vigorous addition to the design optimization framework is proposed to achieve a comprehensive or complete examination. The proposed framework integrates the

functionalities of both HOMER^{Pro} and Matlab/Simulink software to select the optimal LEPS, construct a coordinated power management strategy (PMS), accomplish dependability and power-quality assessments. A case-study for a remote residential community area in Marsa-Matruh, Egypt, is investigated to validate the proposed framework inspired by offering promising solutions to the energy access dilemma. The suggested LEPS involves PV units, WTs, a DsGn, and lead-acid batteries. Following the TEE design optimization procedure, dependability analysis is accomplished by examining the optimal LEPS behaviour against possible changes in the maximum annual capacity shortage. Furthermore, in the end, the results of the comprehensive power-quality assessment during the four seasons of the year are examined and analyzed.

2.4 Enriching the stability and power quality of different LEPSs structures

A particular focus is given to enrich the stability behaviour and voltage quality of different structures of LEPSs due to their fundamental dependence on RESs. Robust control techniques are proposed and integrate distinct types of energy storage devices to enrich the stability and voltage quality of these LEPSs during various variabilities. The addressed instabilities involve the insertion of WT/PV units, normal and extreme variations of RERs (wing gusts and rapid shadow), sudden load rejection, sudden load unbalance, and load changes. The proposed control methods, which mainly depends on the proportional-integral and fuzzy logic controllers, are designed to facilitate the energy storage elements to swiftly charge or discharge power to mitigate the power and voltage fluctuations.

3. Thesis Outline

The thesis is organized into seven chapters as follows:

Chapter 1 firstly presents a broad background along with the distinct motivations for the study. Then the local energy production systems are discussed regarding their structure, significance, and main challenges. Furthermore, a comprehensive literature review on the most related and up-to-date research highlights the concluded research gaps. Finally, the thesis main aims and its organization are respectively summarized.

Chapter 2 describes the detailed modelling of each component utilized in this work inducing the renewables and non-renewable energy sources, the energy storage systems, and the description of fuzzy logic control.

Chapter 3 introduces a detailed demonstration of the proposed methodological techno-enviro-economic (TEE) design optimization framework of LEPSs, which then validated by a case-study aim to provide electricity to a large-scale desalination plant and also supply a number of airport administrative offices, in the new capital of Egypt, with the required electricity, heat and freshwater. The findings are described and analytically examined, showing the significant components' influence on the system's different behaviours.

Chapter 4 proposes a novel fuzzy multicriteria decision-making model for design optimization of LEPSs. The suggested model incorporates the TEE design optimization and a new fuzzy MCDM technique based on F-AHP and F-VIKOR techniques addressing 10 performance criteria and 10 different energy alternatives. Furthermore, sensitivity analysis is also examined to check the optimal system performance against key input variations. Finally, the obtained outcomes are analyzed and discussed.

Chapter 5 introduces the proposed design optimization framework assisted with dependability and power-quality analyses for the optimal LEPS, the framework which integrates both HOMER^{Pro} and Matlab/Simulink software. In publicizing the suggested framework, a case-study involving solar PV, WTs, DsGn, and batteries that aim to supply electricity to a remote residential community area is investigated. In the end, the results of the broad power-quality assessment during the four seasons in the year are analyzed.

Chapter 6 proposes robust control techniques for different structures of LEPSs to enrich the stability behaviour and voltage quality of these LEPSs during diverse types of instabilities. Four different case-studies are examined in this chapter integrating different combination of energy storage technologies.

Chapter 7 concludes the fundamental outcomes and significant contributions of the research. Besides, presenting the potential future directions of the research.

To give a unified picture and facilitate realizing the contents and contributions among the different chapters, Fig. 2 has been introduced to describe the dissertation workflow.

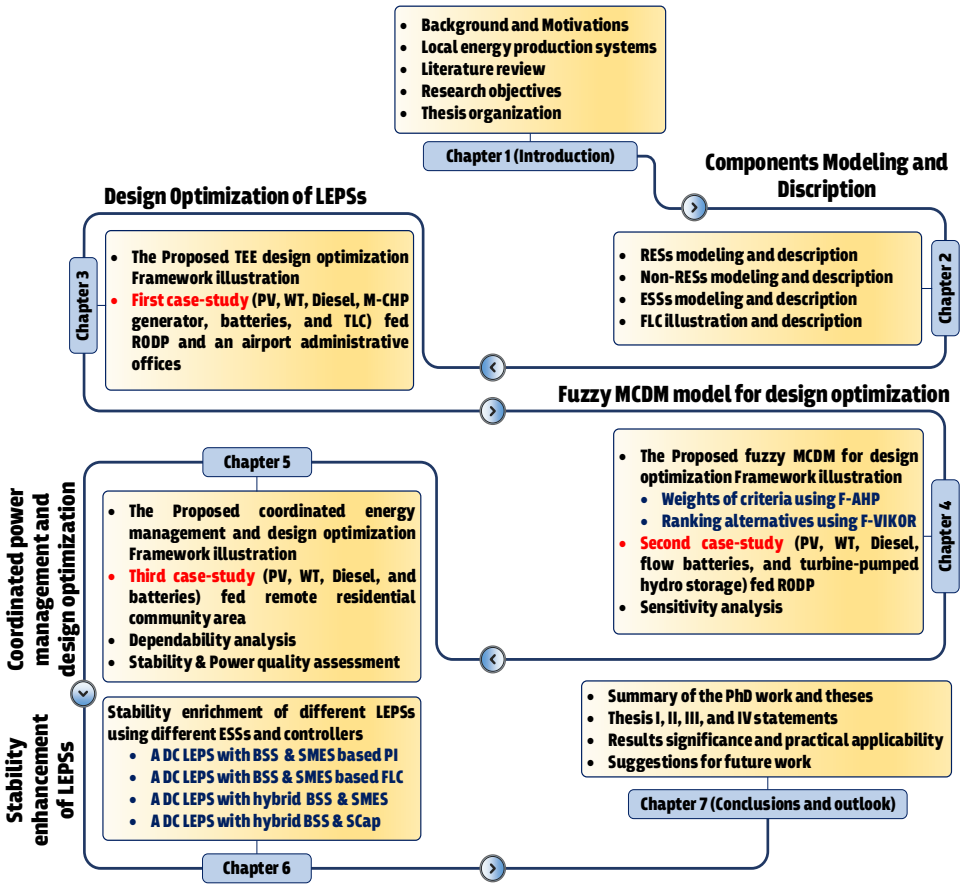

Fig. 2 Structure of the dissertation

4. Theses

4.1 Thesis I

"I have proposed a LEPS to provide electricity, heat, and freshwater for airport facilities. The system planning was performed by developing a systematic techno-enviro-economic optimization framework considering various sustainability aspects for 14 energy alternatives. The proposed LEPS comprises M-CHP and TLC along with PV, WTs, diesel generator, batteries, and a boiler which efficiently fulfilled both electrical and thermal demands with zero capacity shortage with the least amount of GhG. Also, the impact of the different system components on the systems' performances were examined which revealed that integrating the TLC significantly reduced the needed batteries, TNPC, LCOE, and GhG by 90%, 52%, 56.4%, and 36.5%, respectively. Besides, it was found that the optimal system would take only 1.2 years to recover the invested money."

The related work is given in Chapter 3 of the dissertation and was published in [J5] and [J8].

4.2 Thesis II

"I have extended the design optimization framework in thesis-I to involve MCDM analysis since the optimal system selection is significantly influenced by lots of conflicting aspects. To do so, a novel hybrid integration between F-AHP and F-VIKOR decision-making methods has been introduced. The F-AHP was applied to determine the optimal weights of ten different performance criteria then the F-VIKOR was executed to select the winning solution among 10 distinct alternatives optimized by HOMER. The proposed model was validated on a real case-study to electrify a water desalination plant while examining the impact of integrating flow batteries and turbine-pumped hydro storage into the LEPS behaviours. The MCDM analysis revealed the superior results of the WT/PV/DsGn/FBAT. Also, the sensitivity analysis revealed that integrating flow batteries is more economic against demand growth, reduction of storage cost and variation of the interest rate."

The related work is given in Chapter 4 of the dissertation and was published in [J4] and [J6].

4.3 Thesis III

"An integration between HOMER and Matlab/Simulink was accomplished through a series processing solution. The optimal LEPS design, which proposed to supply a remote residential area, was firstly accomplished using HOMER with optimal components' capacities. Then, each element was modelled with its optimal capacity in Matlab/Simulink. Besides, both RERs and loading data employed in HOMER were used in the power quality appraisal by Matlab/Simulink. A coordinated PMS was proposed to supervise the energy interaction and enhance the optimal system stability which revealed its effectiveness in sustaining the system's voltages and powers within standard limits during the instabilities. Besides, the economic results were found consistent and in strong orientation with those in relative studies. Besides, the dependability analysis revealed that at a capacity shortage of 7%, TNPC, LCOE, and GhG were reduced by 13.73%, 8.5%, and 22.5%, respectively."

The related work is presented in Chaptre 5 of the dissertation and has been published in [J9], [C1] and [C2].

4.4 Thesis IV

"I have examined distinct structures of LEPSs integrating different ESSs, such as batteries, SMES, and supercapacitors, and developed different novel and advanced control techniques to boost up the stability and power quality of these LEPSs. The different case-studies were

examined under moderate/extreme climatic variations, balanced/unbalanced loading events, and connection/outage of systems' elements. I have developed a FLC which employ the actual currents of both battery and SMES directly into the control action to reduce calculations and control complexity. Besides, the hybrid BSS-supercapacitors efficiently decreased the maximum voltage overshoot by 55.5% compared to BSS. Also, the hybrid BSS-SMES superiorly alleviated the voltages and powers over- /undershoots by 98%. Finally, this thesis prioritized the utilization of the SMES and the hybrid BSS-SMES as the most superior ESSs in LEPSs."

The related work is presented in Chapter 6 of the dissertation and has been published in [J1], [J2], [J3] and [J10].

5. Significance and Practical Applicability of the Results

At this point, the significance and practical applicability of this research work are explained. With the continual necessity for cost-effective, eco-friendly, reliable, and robust energy production solutions to face the rapid growth of load demands, the depletion of remaining fossil fuels, and the existing lack of access for both electricity and freshwater in different regions globally, a global and national attention is given towards the dependance on lunching RESs-based energy production projects. These projects have to fulfill the international blueprints and agreements such as the sustainable energy for all (SEforALL) [3], the UN sustainable development goals [4], and the Paris Agreement for reducing the GhG emissions [5]. In light with the presented thesis, it is believed that the proposed design optimization framework can efficiently contribute to the international agreements towards spreading the sustainable development and lessening the GhG emissions. Besides, the proposed MCDM design optimization framework could let producing a broad trade-off among a range of competitive energy access choices contemplating distinct sustainability attributes based on realistic perspectives. Furthermore, it can be used as decision-support or managerial tools to generate precise and vigorous strategies to governments, policy-makers, stakeholders, and energy developers for sustainable electrification in different zones around the globe. Based on the investigated case-studies in Egypt, the proposed design optimization frameworks and obtained results offer reliable, cost-effective, and eco-friendly solutions for the current and upcoming water shortage crisis throughout the proposed water desalination projects based-RESs in different location within the country. Besides, proposing economic and reliable solutions to overcome the lack of electricity access problem in remote areas far from the

national electricity grid lines. In spite of the marvelous advantages of depending on RESs, their high penetration levels destructively impact the stability of energy production projects due to their intermittent nature which can impose various instability and power quality difficulties. The different possible instabilities should be investigated to address how the energy system will respond in the presence of different types of ESSs and controllers, the matter which help enhancing the control performance and consequently the energy system functioning. Thus, in this work, a special focus was given to the stability and power quality enhancement of different structures of LEPSs by integrating different types of ESSs and control methods. From the obtained results, the different proposed control approaches efficiently preserved the stability and power quality of a number of LEPSs structures in a wide range of climatic, load, and RESs instabilities. Among the different ESSs, the integration of SMES and the hybrid BSS-SMES systems marvelously maintained the LEPSs stability and facilitated enhancing their power quality which, in turn, can assist in adopting the suggested proposals in real energy systems applications.

6. Research Future Directions

There are several research points around the thesis topic that need more investigation. Emerging research limitations that come from this research include:

- Selecting the most appropriate locations for establishing LEPSs projects throughout developing a geospatial analysis which can also be integrated with MCDM approaches to include a variety of criteria related to sites' selection.
- The design optimization can be enhanced more to include multi-year analyses, which allows the modelling of different changes that can arise over the project course.
- Developing the design optimization by means of metaheuristic algorithms.
- Inspecting the Co-simulation dispatching between HOMER^{Pro} and Matlab software.
- Enhancing the control approach used in enriching the stability of different LEPSs using other advanced control techniques such as the model predictive control.
- Investigating the main influences and disparities between the aggregated and distributed energy storage system on the performance of LEPSs.

7. List of Publications by the Author

Journal publication related to the PhD work

[J1] **Kotb M. Kotb***, M. F. Elmorshedy, H. S. Salama, A. Dán "Enriching the Reliability of Hybrid Renewable DC-bus Microgrid using Battery and Superconducting Magnetic Energy Storage based Fuzzy Logic Approach," Journal of Energy Storage, vol. 45, 2022. **(IF= 6.583, Q1, Indexed: WoS, Scopus, SCIE)**.

[J2] **Kotb M. Kotb***, M. F. Elmorshedy, and A. Dán, "Performance Assessment of Integrating SMES and Battery Storage Systems with Renewable DC-bus Microgrids: A Comparison," Period. Polytech. Elec. Eng. Comp. Sci., vol. 65, no. 4, pp. 382–393, 2021. **(Q4, Indexed: Scopus)**

[J3] M. F. Elmorshedy, M.R. Elkadeem, **Kotb M. Kotb**, I. B.M. Taha, D. Mazzeo, "Optimal design and energy management of an isolated fully renewable energy system integrating batteries and supercapacitors," Energy Conversion and Management, vol. 245, 2021. **(IF = 9.709, Q1, Indexed: WoS, Scopus, SCIE)**

[J4] Z. Ullah, M.R. Elkadeem, **Kotb M. Kotb**, I. B.M. Taha, S. Wang, "Multi-criteria decision-making model for optimal planning of on/off grid hybrid solar, wind, hydro, biomass clean electricity supply," Renewable Energy, vol. 179, 2021. **(IF = 8.001, Q1, Indexed: WoS, Scopus, SCIE)**

[J5] M.R. Elkadeem, **Kotb M. Kotb***, K. Elmaadawy, Z. Ullah, E. Elmolla, B. Liu, S. Wang, A. Dán, S. W. Sharshir, "Feasibility analysis and optimization of an energy-water-heat nexus supplied by an autonomous hybrid renewable power generation system: An empirical study on airport facilities," Desalination, vol. 504, 2021. **(IF = 9.501, Q1, Indexed: Scopus, SCI)**

[J6] **Kotb M. Kotb***, M.R. Elkadeem, A. Khalil, S. M. Imam, M. A. Hamada, S. W. Sharshir, A. Dán, "A fuzzy decision-making model for optimal design of solar, wind, diesel-based RO desalination integrating flow-battery and pumped-hydro storage: Case study in Baltim, Egypt," Energy Conversion and Management, vol. 235, 2021. **(IF = 9.709, Q1, Indexed: WoS, Scopus, SCIE)**

[J7] M.R. Elkadeem, **Kotb M. Kotb**, Z. Ullah, E. G. Atiya, A. Dán, S. Wang, "A two-stage multi-attribute analysis method for city-integrated hybrid mini-grid design," Sustainable Cities and Society, vol. 65, 2021. **(IF = 7.587, Q1, Indexed: Scopus, SCIE)**

[J8] K. Elmaadawy, **Kotb M. Kotb**, M.R. Elkadeem, S. W. Sharshir, A. Dán, A. Moawad, B. Liu, "Optimal sizing and techno-enviro-economic feasibility assessment of large-scale reverse osmosis desalination powered with hybrid renewable energy sources," Energy Conversion and Management, vol. 224, 2020. **(IF = 9.709, Q1, Indexed: WoS, Scopus, SCIE)**

[J9] **Kotb M. Kotb***, M.R. Elkadeem, Mahmoud F. Elmorshedy, A. Dán, "Coordinated power management and optimized techno-enviro-economic design of an autonomous hybrid renewable microgrid: A case study in Egypt," Energy Conversion and Management, vol. 221, 2020. **(IF = 9.709, Q1, Indexed: WoS, Scopus, SCIE)**

[J10] H. S. Salama, **Kotb M. Kotb**, I. Vokony, A. Dán, "The role of hybrid Battery-SMES energy storage in enriching the permanence of PV-Wind DC-Microgrids: A case-study," Eng, Vol. 3(2), 207-223, **(Q4, Indexed: Scopus)**

Peer-reviewed conference papers related to the PhD work

[C1] **Kotb M. Kotb***, M. F. Elmorshedy and A. Dán, "Permanence Improvement of a Local Energy Production System Including Unbalanced Loading," International IEEE Conference and Workshop in Óbuda on Electrical and Power Engineering, pp. 185-190, Budapest, Hungary, 2019.

[C2] M. F. Elmorshedy, **Kotb M. Kotb*** and A. Dán, "Hybrid Renewable Microgrid System Based DC-bus Scheme for Residential Load Applications," 22nd International Conference on Electrical Machines and Systems, pp. 1-6, Harbin, China, 2019.

[C3] **Kotb M. Kotb***, S. M. Said, A. Dán and B. Hartmann, "Stability Enhancement of Isolated-Microgrid Applying Solar Power Generation Using SMES Based FLC," 7th International Istanbul Smart Grids and Cities Congress and Fair, pp. 104-108, Istanbul, Turkey, 2019.

Journal publication not related to the PhD work

[J11] A.S. Zalhaf, B. Elboshy, **Kotb M. Kotb**, Y. Han, A.H. Almaliki, R. Aly, M.R. Elkadeem, "A High-Resolution Wind Farms Suitability Mapping Using GIS and Fuzzy AHP Approach: A National-Level Case Study in Sudan," in Sustainability, vol. 14, no. 1, 2022.

[J12] H. U. R. Habib, U. Subramaniam, A. Waqar, B. S. Farhan, **Kotb M. Kotb** and S. Wang, "Energy Cost Optimization of Hybrid Renewables Based V2G Microgrid Considering Multi Objective Function by Using Artificial Bee Colony Optimization," in IEEE Access, vol. 8, pp. 62076-62093, 2020.

[J13] E. Al-Ammar, H. U. R. Habib, **Kotb M. Kotb**, S. Wang, W. Ko, M. F. Elmorshedy, A. Waqar, "Residential Community Load Management Based on Optimal Design of Standalone HRES With Model Predictive Control," in IEEE Access, vol. 8, pp. 12542-12572, 2020.

[J14] H. U. R. Habib, S. Wang, A. Waqar, B. S. Farhan, **Kotb M. Kotb** and Y-S. Kim, "Combined Heat and Power Units Sizing and Energy Cost Optimization of a Residential Building by Using an Artificial Bee Colony Algorithm," in IEEE Access, vol. 8, pp. 218289-218303, 2020.

Peer-reviewed conference papers not related to the PhD work

[C4] H. U. R. Habib, S. Wang, B. S. Farhan, H. W. Salih, A. Waqar and **Kotb M. Kotb**, "Load Power Smoothing and DC Bus Voltage Control of PV-SMES Standalone Microgrid based Variable Speed DG using FLC-MPC Approach," 3rd International Conference on Energy Conservation and Efficiency, pp. 1-6, Lahore, Pakistan, 2019.

[C5] H. U. Rahman Habib, S. Wang, M. F. Elmorshedy, A. Waqar, R. M. Imran, and **Kotb M. Kotb**, "Performance Enhancement of Power Converters for PV-Based Microgrid using Model Predictive Control," International Conference on Electrical, Communication, and Computer Engineering, Swat, Pakistan, pp. 1-6. 2019.

[C6] **Kotb M. Kotb***, A. E. Hassan and E. M. Rashad, "Implementation of genetic algorithm-based SHE for a cascaded half-bridge multilevel inverter fed from PV modules," 20th International Conference on Electrical Machines and Systems, pp. 1-6, Sydney, Australia, 2017.

[C7] **Kotb M. Kotb***, A. E. Hassan and E. M. Rashad, "Simplified sinusoidal pulse width modulation for cascaded half-bridge multilevel inverter," 18th International Middle East Power Systems Conference, pp. 907-913, 2016.

[C8] **Kotb M. Kotb***, A. E. Hassan and E. M. Rashad, "Genetic Algorithm Implementation for Minimizing Harmonic Distortion in Cascaded half-bridge Based Multilevel DC Link Inverter," 1st International Conference on New Trends for Sustainable Energy, Alexandria, Egypt, 2016.

[C9] **Kotb M. Kotb***, A. E. Hassan and E. M. Rashad, "Minimization of Total Harmonic Distortion for an Asymmetric Multilevel Inverter Fed from Photovoltaic Modules," 1st Future University International Conference on New Energy and Environmental Engineering, Cairo, Egypt, 2016.

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[5] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement