AUS | الجامعة الأميركية في الشارقة
American University of Sharjah

Petrofac Research Chair in Renewable Energy
AY21-22 Activity Report

August 2022

This report presents a summary of the research activities conducted in the Renewable Energy Research Center (RERC) during the academic year 2021-2022.

I. SHCOLARLY ACTIVITIES

A. Current Research Activities

Coordinated many project activities in the Renewable Energy Research Center (RERC) with a multidisciplinary research team from the CEN:

1) Remote monitoring of a rooftop PV system

   In collaboration with I. Zualkernan (COE) and the Lab Instructor S. Shapsough.

2) Modeling and characterization of dust accumulation on PV panels

   In collaboration with A. Al-Othman (CHE), A. Aidan (CHE), and the research assistant R. Zannerni.

   The project activities are carried out on the PV panels installed on the ESB rooftop PV system.

3) Design of a large solar quadrotor

   In collaboration with the research assistant (VGiR) Ajmal Roshan and MSMTR student Ishaq Hafez.

   The project objectives are to design and build a solar powered quadrotor with long-endurance flight that is able to autonomously navigate and scan the area of a large solar farm.

4) Involved graduate and undergraduate students and research assistants in the RERC research activities.

B. Pilot Projects

1) Rooftop PV System

The PV facility (with approximately 8 kW capacity) has been installed on the rooftop of the new engineering building. Installation has been completed in May 2021 and final commissioning is expected to be carried out during early fall 2022.

The ongoing research activities include:

- Coordinating the final installation and commissioning stage of the ESB rooftop PV Test Facility for the Renewable Energy Research Center.
- Coordinating the design and development of the monitoring system for the PV Test Facility on the rooftop of ESB to study the characteristics of solar panels and the effect of atmospheric condition on their efficiency. The system will be used to support the research activities of the Renewable Energy Research Centre. In collaboration with I. Zualkernan (COE), S. Shapsough (COE Lab Assistant), and two graduate and undergraduate students.

Fig. 1 shows a top view of the rooftop solar facility. The system includes two rows of PV panels with two different PV cell technologies: one row with monocrystalline panels (grey shade) and one row with polycrystalline panels (blue shade).

The rooftop PV system will allow to

- study long-term reliability and performance of PV modules with different PV cell technologies
- accurately predict the annual energy production of PV systems for our geographical location
- build a database to develop, improve, and validate the needed simulation models

Fig. 1 Top view of the ESB rooftop solar test facility

2) Solar Quadrotor

The objective of this project is the design and development of a new autonomous quadcopter platform combining an onboard solar panel to extend the flight operating time. We present the design challenges of large-scale quadcopters with flexible frames that incorporate on-board arrays of solar cells, and we propose a dynamic model of a

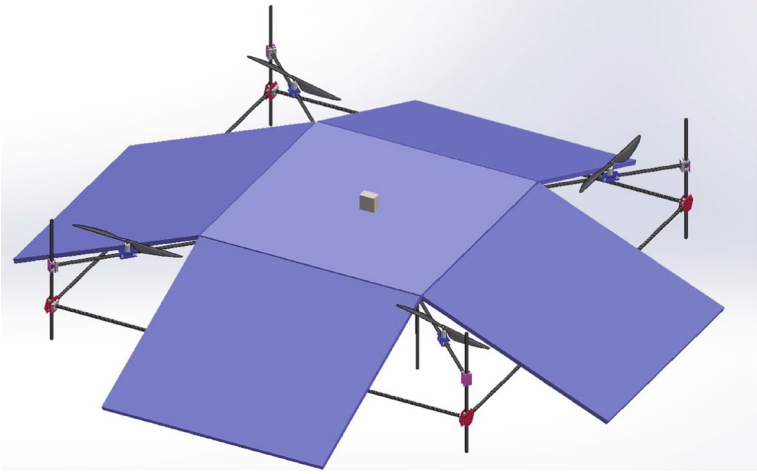
customized quadcopter with analysis of the aerodynamic influence using computer-aided design tools [6], [10].

For quadcopters with flexible frames, it is difficult to use the Euler-Lagrange or Newtonian approach to derive the dynamic model as is done with small and rigid quadrotors. Many relevant factors that lead to the consideration of the distributed flexibility should be analyzed. To deal with this challenge, an optimal approach for sizing the frame and platform structure is followed. This is achieved by using a modern approach to computer modeling of quadcopters through the integration process of SolidWorks CAD modeling and MATLAB/Simulink environments.

Designing and testing flight control algorithms for quadrotor UAVs (unmanned aerial vehicles) is not an easy task due to the risk of possible danger and damage during the practical flight. In order to improve the safety and efficiency of the flight control implementation, a testbed with four degrees of freedom for quadrotor UAVs is developed. The testbed is equipped with a DSP (digital signal processor) board. The DSP board is utilized as the target computer, and a laptop PC is employed as the host computer as well as flight visualization computer which runs to show visual data, such as orientation and altitude of the quadrotor UAV. This testbed can be utilized for simulating various flight control algorithms, without losing safety and reliability. To demonstrate the effectiveness of the proposed testbed, a stabilization control algorithm will be developed and verified under various operating conditions.

Fig. 2 shows the first quadrotor prototype which was built in the Lab and the improved design in SolidWorks. Fig. 3 shows the developed testbench for the quadrotor testing and evaluation.

(a)



(b)

Fig. 2. Quadcopter frame design: (a) First prototype which was built in the Lab, (b) New improved frame design

Fig. 3. Quadcopter testbench

II. OUTREACH ACTIVITIES:

1) Invited as a Visiting Scholar at the Data Science Program, The George Washington University (GWU), USA, May 24 – June 23, 2022. The research visit allowed to establish research collaboration with faculty at GWU and initiate a project proposal for possible funding from

NSF. The research visit is featured on the GWU website https://blogs.gwu.edu/ccas-global/ay21-22-visiting-scholars/.

2) Participated as a faculty representative of AUS in the DEWA Sustainability Report - Materiality Workshop, Nov. 3, 2021.

3) Delivered a presentation to Petrofac outlining the research activities in renewable energy at AUS, AUS-Petrofac annual meeting, Wednesday, November 10, 2021.

4) Coordinated with the AUS Media Department and Petrofac to promote the research work conducted under the Petrofac Research Chair in Renewable Energy Endowment.

III. RESEARCH PUBLICATIONS (2021–2022)

a) Book Chapters

[1] A. Adib, and R. Dhaouadi, "Dynamic Analysis and Optimized Design of Synergetic Control for a PMSM Drive System", in Advances in Service Robots [Working Title]. London, United Kingdom: IntechOpen, April 20th, 2022. Available: https://doi.org/10.5772/intechopen.104206 .

b) Refereed Journal Publications

[2] A.R. Sajun, S. S. E. Shapsough, I. A. Zualkernan, R. Dhaouadi, "Edge-Based Individualized Anomaly Detection in Large-Scale Distributed Solar Farms," ICT Express Journal, In Press, ISSN 2405-9595, https://doi.org/10.1016/j.icte.2021.12.011.

[3] R. Dhaouadi, A. Al-Othman, A. Aidan, M. Tawalbeh, and R. Zannerni, "A characterization study for the properties of dust particles collected on photovoltaic (PV) panels," Renewable Energy, vol. 171, pp. 133-140, June 2021, https://doi.org/10.1016/j.renene.2021.02.083.

[4] R. Dhaouadi, M. Takrouri, and I. Hafez, "High Precision Sinusoidal Tracking Control of a Voice-Coil Linear Servomotor with Nonlinear and Uncertain Parameters," Revised and resubmitted to the IEEE Open Journal of the Industrial Electronics Society, manuscript No. 22-OJIES-0079, 26 July 2022.

[5] A. Al-Othman, R. Dhaouadi, A. Aidan, M. Tawalbeh, and R. Zannerni, "Novel Self-Cleaning Coatings based on Zirconium Phosphates for Solar Panels," to be submitted to the International Journal of Thermofluids as an invited paper for the special issue from SEEP 2021.

c) Refereed Conference Publications

[6] A. Roshan and R. Dhaouadi, "CAD Modeling and Simulation of a Large Quadcopter with a Flexible Frame," Accepted for presentation at the Future Technologies Conference (FTC 2022), 20-21 October 2022, Vancouver, Canada.

[7] I. Hafez and R. Dhaouadi, "Application of Particle Swarm Optimization for the Identification of Two-Mass Electric Drive Systems," Proceedings of the International Conference on Control, Decision, and Information Technologies (CODIT'22), Istanbul, Turkey, 17-20 May 2022.

[8] O. Alkurdi and R. Dhaouadi, "Design and Optimization of a Nonlinear Controller for Flexible Drive Systems," Poster Presentation, UAE GSRC 2022 Graduate Students Research Conference, Dubai, UAE, 24 March 2022.
[9] I. Hafez and R. Dhaouadi, "Parameter Identification of DC Motor Drive Systems using Particle Swarm Optimization," Proceedings of the 7th International Conference on Engineering and Emerging Technologies (ICEET), pp. 1-6, 27-28 October 2021, Istanbul, Turkey, https://doi.org/10.1109/ICEET53442.2021.9659664.
[10] R. Dhaouadi, M. Takrouri, S. Shapsough, and Q. Bashayreh, "Modelling and Design of a Large Solar Quadcopter," In: Arai K. (eds) Proceedings of the Future Technologies Conference (FTC) 2021, Volume 1. FTC 2021. Lecture Notes in Networks and Systems, vol 358. Springer, Cham. https://doi.org/10.1007/978-3-030-89906-6_30.
[11] R. Dhaouadi, A. Al-Othman, A. Aidan, M. Tawalbeh, and R. Zannerni, "Novel Self-Cleaning Coatings for Solar Cells," Poster presentation, 12th International Conference on Sustainable Energy and Environmental Protection (SEEP 2021), University of Natural Resources and Life Sciences, Vienna (BOKU), Austria, 13-16 September 2021.
[12] A. Jafari and R. Dhaouadi, "Adaptive Control of a Robot Arm with Flexible Joint Using Machine Learning," Submitted to the 2023 IEEE/SICE International Symposium on System Integrations (SII 2023), Atlanta, GA, USA, January 17-20, 2023.

IV. CONFERENCE AND WORKSHOP ORGANIZATION

- Organizing Committee Chair, AUS Workshop on DSP Based Control of Motor Drives using AltAir Embed, American University of Sharjah, November 2022.
- General Co-Chair, 7th International Conference on Electric Power and Energy Conversion Systems (EPECS'23), to be held tentatively at AUS, October 2023.

V. INTERNATIONAL RESEARCH COLLABORATION

1) Research visit to the Data Science Program, The George Washington University during summer 2022.
   The research visit allowed me to interact with two researchers affiliated with the Data Science Program at the George Washington University (GWU):
   - Dr. Amir Jafari, Assistant Professor (GWU) and
   - Dr. Reza Jafari, Associate Professor and Director of the electrical engineering program at the East Coast Polytechnic University in Northern Virginia, and Adjunct faculty at GWU.

   Both researchers are actively working in the areas of statistical modeling & control using recurrent neural networks, time series analysis modeling & forecast using Deep Learning.

   The visit allowed to establish research collaboration in the area of machine learning for control systems and the initiation of two research projects namely,
   a) Modeling and Control of a Large Solar-Powered Quadcopter using AI and Machine Learning
   b) Adaptive Control of a Robot Arm with Flexible Joint Using Machine Learning

2) Research and Teaching collaboration in the area of motor drives with Prof. Duco Pulle.
Prof. Dr. ir. Duco W. J. Pulle
Univ. Prof., RWTH-ISEA Aachen, Germany
CEO, EMsynergy Sydney, Australia

Prof. Duco will conduct a research visit to AUS as a Visiting Scholar during Fall 2022. The plan of activities is the development of an embedded Lab for electric drive systems to support the MSc Courses ELE644 and MTR644, and to organize a one-day workshop on using Altair Embed and TI-DSP platforms for motor drives.

VI. RESEARCH GRANTS

1. Awarded an OAP Grant (#OAP22-CEN-092) from the AUS Open Access Program (OAP), Amount: AED 6,000 (March 2022).

2. Continuing Grant:

   Smart City Research Institute (SCRI), Grant Proposal 2018 (SCRI18-CEN-02), "Using IoT and Big Data to Monitor Large-Scale Distributed Solar Farms in Smart Cities," January 2019 – May 31, 2022.

   PI: Imran Zualkernan. Co-PIs: Rached Dhaouadi, Shayok Mukhopadhyay and Habib-ur Rehman. Two-year proposed budget: AED 900,000.

   The SCRI project was initiated and conducted as part of the research activities of the renewable energy center. The project funding was used to build an additional solar test facility to complement the ESB rooftop PV system, which was sponsored by the Petrofac fund. The following is a summary of the research aspects of the project conducted by the research team.

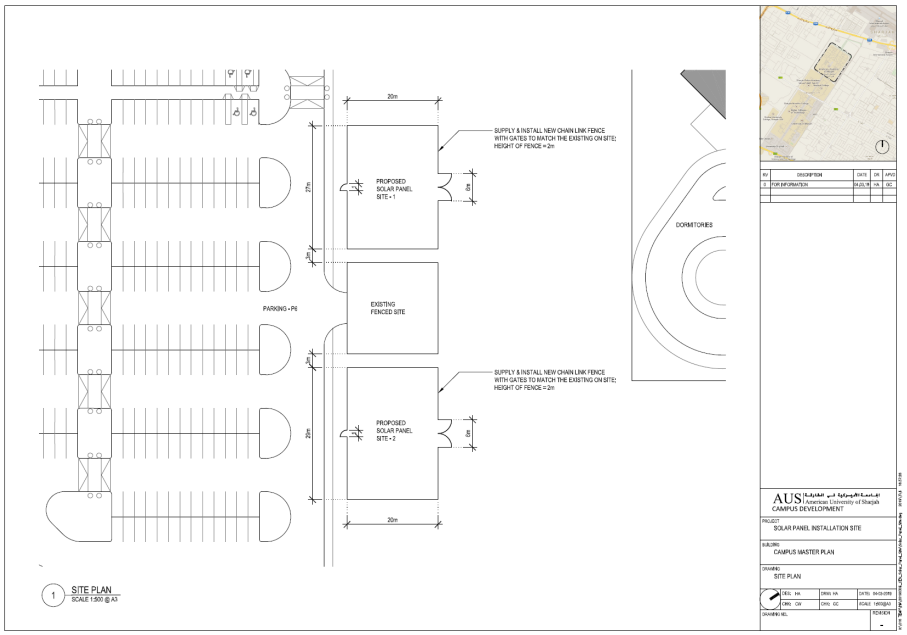
   Project Objectives:

   - The objective of this research is to apply Internet of Things (IoT) and big data technologies to enable monitoring and eventually intelligent control of large solar parks (> 100 MW) as well as smaller and distributed solar parks (< 2MW).
   - Like many other smart city services, Internet of Things (IoT) can be the core for smart energy services as well.
   - The proposal is to build a prototypical distributed solar energy system that is instrumented using the latest IoT and big data technologies to collect, process, store and analyze the data being collected in an almost real-time fashion.
   - The small solar farm can serve as a platform for future research in solar energy to study different PV panels technologies such as bifacial PVs. The farm will also include Lithium and Lead Acid batteries to study their performance under the UAE weather conditions.

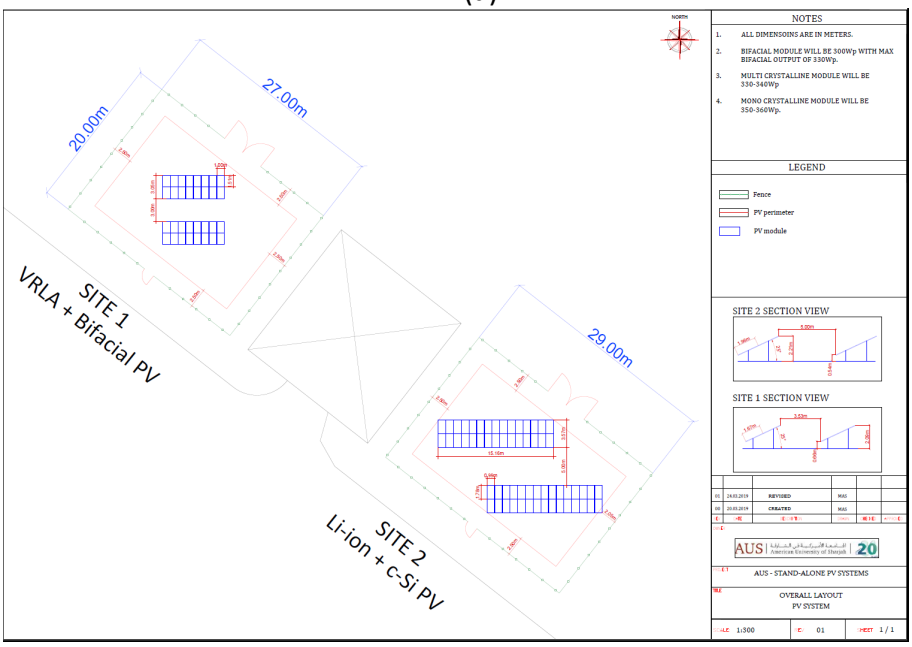
   The solar farm was designed and developed in the parking area #6 of AUS. All equipment including PV panels, controllers and batteries have been installed as shown in Fig. 4. The solar farm electrical load has been identified. The research team has also received

approval for installing LoRaWAN towers on campus to network build infrastructure for the edge devices.

Current activities are focusing on the development of the system instrumentation, the edge hardware and network as well as the design of the software architecture. Final commissioning is expected to be to be carried out at the end of 2023.



(a)



(b)

Fig. 4 Solar farm layout. (a) Location of the solar farm, (b) Top view of the PV panels layout, (c) solar farm section with bifacial PV modules

VII. RESEARCH TEAM

Faculty:

- Rached Dhaouadi (ELE)
- Imran Zualkernan (COE)
- Habib-ur Rehman (ELE)
- Shayok Mukhopadhyay (ELE)
- Amani Al-Othman (CHE)

Senior Lab Instructor:

- Ahmed Abdulla Aidan (CHE)

Research Assistants:

- Salsabeel Shapsough (MSc, COE)
- Ajmal Roshan (VGiR)

Graduate Students:

- Ishaq Hafez (MSc, MTR)
- Ali Sajun (MSc, COE)