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*Editorial*

# Rethinking the Distribution Power Network Planning and Operation for a Sustainable Smart Grid and Smooth Interaction with Electrified Transportation

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**Abstract:** This editorial document provides the main motivations and a brief description of each paper published in the "Rethinking the Distribution Power Network Planning and Operation for a Sustainable Smart Grid and Smooth Interaction with Electrified Transportation" Special Issue. This Special Issue aims to present several innovative solutions on planning and operation of distribution power networks under smart grid paradigm where prosumers, electric vehicles, and other typical loads are usually connected. Some of those solutions and computational applications were covered in this Special Issue, namely probabilistic power flow, voltage and power factor control, agent-based simulation, digital twin, resilient energy scheduling, and uncertainty modeling are among the contributions. The published works are very timely and are of great interest, which will certainly drive the impact of future researchers in the near term concerning the field of this Special Issue.

**Keywords:** digital twin; electric vehicles; probabilistic power flow; smart building; special issue



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## 1. Introduction

The current transformation of power systems towards decarbonization needs to accelerate to achieve the required renewable energy target of 32% in EU by 2030. The panic in global energy markets created by the pandemic has exposed some problems underlying our energy systems while the world moves towards a cleaner energy system. The pandemic ignited electric vehicle (EV) sales, which apparently caused no significant threat to the original EV massification plan. Nevertheless, the real boom is yet to happen in the coming years. Therefore, energy system operators need to make significant efforts to make this shift as soon and smooth as possible without disruptions and inadequate investment decisions. Policymakers have a fundamental role in driving this transition's success and guaranteeing fairness among all system players.

The introduction of renewable energy generation and the forthcoming EV revolution disrupted distribution power network planning and operation. The new paradigm of the smart grid is a real challenge that is being taken seriously by many experts and researchers around the world, which are leveraging the full potential of artificial intelligence tools and classical optimization to solve challenging real-world problems [1,2]. Artificial intelligence methods will certainly play a very important role in this field. Indeed, the guest editorial team has launched yearly algorithm competitions at international venues in the field of power and energy systems and artificial intelligence since 2017. These competitions aim to bridge the gap between computer scientists and energy engineers working in energy industry problems. The 2021 algorithm competition has been launched and welcomed 3 important venues, namely at IEEE Congress on Evolutionary Computation (CEC) 2021, GECCO 2021, and IEEE PES General Meeting 2021 (The algorithm competition website can be found at http://www.gecad.isep.ipp.pt/ERM-competitions, accessed on

20 October 2021). In addition, a special session has been held in IEEE CEC 2021 in parallel to the algorithm competition, which attracted some contributions to this issue. An article from Prof. Rivera's team [2], participants of the 2021 competition, has been published in this Special Issue departing from their work for the event.

This editorial paper is organized as follows. After this introductory section, Section 2 presents a brief description of each paper accepted in this Special Issue. Finally, Section 3 provides the most relevant conclusions.

## 2. Contributors' Description

The papers that contributed to this Special Issue have been carefully selected after a rigorous peer-review process conducted by the Guest Editors and the Energies Editorial board. These contributions discuss and propose several innovations that can contribute to a smoother energy transition, focusing on distribution grid planning and operation of a sustainable smart grid, which inherently will be characterized by a high number of electric vehicles. A summary of each paper published in the Special Issue is given bellow:

- Probabilistic Load Flow Algorithm of Distribution Networks with Distributed Generators and Electric Vehicles Integration [3].

This work highlights the need for sophisticated methods to deal with the increasing penetration of distributed generators and electric vehicles, which are an increased source of uncertainty for grid planning and operation. The paper proposes a probabilistic load flow (PLF) algorithm consisting of an Improved Latin Hypercube Sampling Cumulant Method, as the authors name it, where the cumulants of the input variables are obtained based on sampling results. The probability distribution functions of wind and solar power, EVs, and load demand are considered for the sampling methods. The test study comprises an IEEE 30-bus network fully loaded with DG and EVs. The results demonstrate that PLF is an important and necessary tool for the future of distribution power networks.

- A Mixed Binary Linear Programming Model for Optimal Energy Management of Smart Buildings [4].

This paper deals with a novel concept for smart buildings proposing an energy management model to reduce the peak consumption and electricity consumption costs from the building's perspective. A mixed binary linear programming is formulated considering the constraints of a battery, solar power on the rooftop, and EVs for each apartment. If the novel concept becomes a reality in the upcoming years, there is a great potential to reduce up to 65% of the peak demand requested by the external grid, and the owner of the building can save as much as 28% in energy costs.

- Enhanced Coordination Strategy for an Aggregator of Distributed Energy Resources Participating in the Day-Ahead Reserve Market [5].

The research work carried out in this paper proposes a DER management approach for energy aggregators to tackle distribution network issues. The proposal includes the aggregator's participation in the day-ahead reserve market. The optimization model is formulated as a linear programming model to maximize the aggregator profits. The EV charging control is considered to provide a regulation reserve for the market. The case study uses a MV network with a level of 24.9 kV and a low-voltage level of 220V in the secondary grid, populated with 660 EVs and two DERs. The results suggest that the aggregator strategy application can improve the aggregator's profits and electrical distribution grid operation.

- Schedule Optimization in a Smart Microgrid Considering Demand Response Constraints [2].

This work falls in the line of research of the previous paper [5] and focuses on including demand response (DR) function in energy scheduling for the smart grid operation. The researchers stress the importance of uncertainty sources that need to be considered, such as EVs, renewable sources, electricity market prices, and loads with DR. The variable

neighborhood search and differential evolutionary particle swarm optimization (VNS-DEEPSO) are combined to address the optimization problem. Authors adopt 0-1 knapsack problem (0-1 KP) and DR function (DRF) to be compared. The former groups demand in the search space limits while the DRF works with the continuous variables and requires no discretization. Authors suggest that DRF has several advantages over 0-1 KP because it is computationally lighter and yields accurate solutions.

- IoT-Based Digital Twin for Energy Cyber-Physical Systems: Design and Implementation [6].

This paper presents a design and implementation methodology for the digital twin (DT) concept in the context of energy cyber-physical systems (ECPS). DT aims to be a live replica of the power systems grid in digital means as realistic as possible (twin) to the physical counterpart. The DT platform can also be used to test low-bandwidth and high-bandwidth multiple applications before deployment in the real world to avoid premature failures or untested issues. The concept is tested in Amazon Web Services as the main cloud service for the DT platform. The results published by the authors indicate that the DT is feasible for the real-time implementation of ECPS to maintain errors below 4% level and mimic the dynamics and events of the real grid. Furthermore, the DT can reconstruct voltage estimates with an accuracy of 98.2% in the tested scenario.

- An Agent-Based Approach for the Planning of Distribution Grids as a Socio-Technical System [7].

The work above falls in the scope of agent-based simulation for studying the behavioral aspects of energy consumers. The behavioral aspects are key issues for planning increasingly complex power systems since users can play an important role by affecting electricity consumption. Four types of consumers categories are established from high-income to early adopters. The behavioral model is coupled with a real distribution network and customer load demand. The results suggest that the little changes in the behavior of different residential consumers can have considerable differences in the grid power flow and voltage levels.

- Voltage Reduction in Medium Voltage Distribution Systems Using Constant Power Factor Control of PV PCS [8].

The voltage reduction challenge in MV distribution systems due to the rising penetration of photovoltaic systems and renewable generation is addressed in this paper. Several ideas are discussed to mitigate the voltage increase. The constant power factor for low-voltage PV systems is widely used as a voltage rise countermeasure in distribution systems, and it is studied for a real MV distribution system in the Kyushu area of Japan. Authors conclude that the constant power factor control worsens voltage rise in MV distribution systems since there is an increase in reactive power losses due to reverse power flow. Nevertheless, the power factor control works effectively in the low-voltage side of the distribution grid. Authors recommend distribution grid operators to determine if the voltage reduction problem happens due to a reverse power flow in MV distribution lines.

- Voltage Control Strategy for Energy Storage System in Sustainable Distribution System Operation [9].

Traditional voltage control strategies are not adequate for the large proliferation of DERs. Therefore, this research work proposes easy to implement sensitive-based voltage control for energy storage systems. Their strategy uses a single measure of the terminal voltage in the energy storage to determine the reactive power of each phase. The case study considers an industrial distribution grid in Northwest Washington with a high DER penetration rate. Authors claim that the results mitigate, under various conditions, voltage unbalances, improved voltage levels, and power factor correction, which consequently provide a good contribution to a sustainable distribution system operation.

## 3. Conclusions

A large set of new technologies and applications can improve the planning and operation of sustainable power systems. A sustainable smart grid and smooth integration of electric vehicles should translate into improved use of renewable energy sources, reduced climate impact, improved reliability, fewer failures, cheap energy cost, and efficient coordinated charging of electric vehicles.

In this Special Issue, some of these technologies and computational applications have been discussed for the planning and operation of future distribution grid systems. The reader will find contributions that include agent-based simulation, digital twin, probabilistic power flow, robust energy scheduling, voltage and power factor control, and uncertainty modeling. The papers published in this Special Issue are very timely, and they will certainly drive the impact of future researchers in the near term concerning the theme *Rethinking the Distribution Power Network Planning and Operation for a Sustainable Smart Grid and Smooth Interaction with Electrified Transportation*. Therefore, we are happy to invite the readers to dive into the papers published in this Special Issue and discover remarkable findings that are only briefly summarized in this editorial outline.

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