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Review

Operational Issues of Contemporary Distribution Systems: A Review on Recent and Emerging Concerns

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Abstract: Distribution systems in traditional power systems (PS) constituted of passive elements and the distribution issues were then limited to voltage and thermal constraints, harmonics, overloading and unbalanced loading, reactive power compensation issues, faults and transients, loss minimization and frequency stability problems, to name a few. Contemporary distribution systems are becoming active distributed networks (ADNs) that integrate a substantially increasing amount of distributed energy resources (DERs). DERS include distributed generation (DG) sources, energy storage resources and demand side management (DSM) options. Despite their evidenced great benefits, the large-scale deployment and integration of DERs remain a challenge as they subsequently lead to the network operational and efficiency issues, hampering PS network reliability and stability. This paper carries out a comprehensive literature survey based on the last decade's research on operational challenges reported and focusing on dispatchable and non-dispatchable DGs grid integration, on various demand response (DR) mechanisms and, on battery energy storage system (BESS) charging and discharging challenges, with the aim to pave the way to developing suitable optimization techniques that will solve the coordination of multiple renewable sources, storage systems and DRs to minimize distribution systems' operational issues and thus improve stability and reliability. This paper's findings assist the researchers in the field to conduct further research and to help PS planners and operators decide on appropriate relevant technologies that address challenges inherent to DG grid integration.

Keywords: demand response strategies; demand side management; distributed energy resources; battery energy storage systems; distribution generation; operational challenges; optimization techniques

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1. Introduction

1.1. Traditional vs. Contemporary PS Networks

From the first built PS network, more than 100 years have seen a huge development of the electricity generation and supply systems. Points of generation of electric power were indeed situated several kilometres away from points of consumption as shown in Figure 1, since for economic reasons and a secure supply of electrical power, long distance bulk power transfer was essential [1]. Until the 1990s, the electric power industry was inclined to have a vertical integration approach to generation and transmission, justified mostly by economic reasons as mentioned above, rather than the improvement of the overall efficiency/reliability of the system [2].

The quasi-increasing amount of diverse electrical nature's loads over time resulted in the change of the grid topology, prompting grid complexity growth as illustrated in Figure 2, requiring much more attention on PS operational issues than ever. Current transformations have been driven for the last two decades by the increasing integration of renewable energy sources (RES), particularly solar and wind sources, known for their intermittency and unpredictability, into national grids.

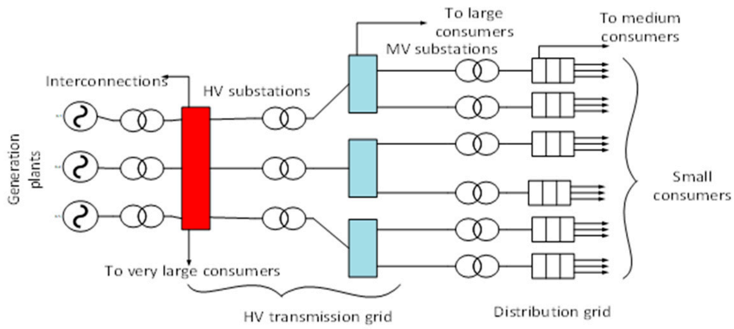

Figure 1. Traditional PS network topology.

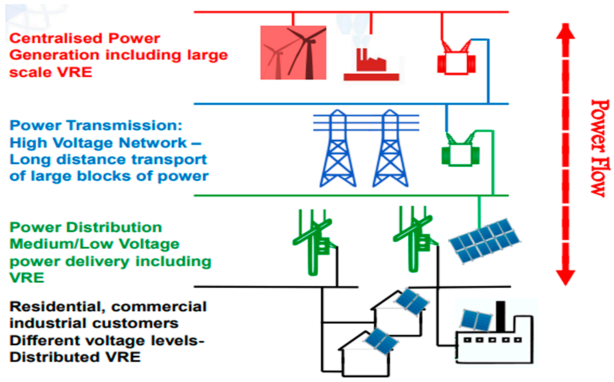

Figure 2. Contemporary network topology [3].

These transformations, commonly referred to as Smart Grid (SG), provide a combination of electrical power infrastructure with modern distributed computing facilities and communication networks [4]. Interest in RES grid integration has indeed developed because of the exponentially increasing demand for power delivery, a more secure energy future and energy policies adopted by governments in an effort to reduce CO_2 and greenhouse gas emissions [5–7]. Integration of renewable DGs, the most popular of them being solar and wind, into PS has positive and negative impacts on both power utilities and customers. Indeed, RES grid integration has evidenced substantial technical, environmental and economic benefits but at the same time, their increasing penetration leads to technical issues such as reverse energy flow from the customer end back into the transmission system [4], with negligible or reduced reactive power contribution [8,9]. One essential criterion for PS stability is to continuously balance power generation and consumption. Since for various reasons, the demand is volatile, generation must be flexible to accommodate the demand at any time [10]. The need to curtail consumers' peak hours and fill the gap caused by the mismatch between the amount of power generated and consumed at a specific time has become a very challenging task [11] for PS network researchers and operators.

1.2. Wind and PV Solar Trends and Contribution to Global Energy

The wind and solar-based RES footprint has been growing rapidly as shown in Table 1. Data extracted from the U.S. Energy Information Administration (EIA) indicate that from 2011 the global energy production increased by 28.59 % over a period of 10 years [12]. From a 2.36 % contribution to the global energy production in 2011, the combined solar PV and wind energy production has reached 10.41 % contribution to the world electricity generation in 2021.

Table 1. Solar PV and wind electricity generation growth from 2011 to 2021.

Energy Source/Activity	2011	2016	2021
Total Generation [billion kWh]	21,226	23,971	27,295
Solar [billion kWh]	66	341	1035
Wind [billion kWh]	435	957	1808

According to the International Renewable Energy Agency (IRENA), it is projected that in the next three decades, about 65% of the world energy will be produced from RES as shown in Figure 3 [13]. Consequently, the complexity of distribution issues will continue to grow with the increase of the number of DERs and micro grids (MG), especially because of the fact that most solar is connected to the DS rather than to the transmission system. PS networks will continue to encounter numerous variabilities, affecting fundamentally the planning and the operation of the electric distribution system, both technically and economically, prompting on one side the upgrade of the aging electricity infrastructure and on the other side, a subsequent transformation of the PS into Smart Grid (SG) process otherwise referred to as Grid modernisation. Uluski et al. in [14] project that the next generation distribution management shall need to incorporate more intelligence and advanced functionality to support these changes in the operation, monitoring and control of the distribution grid.

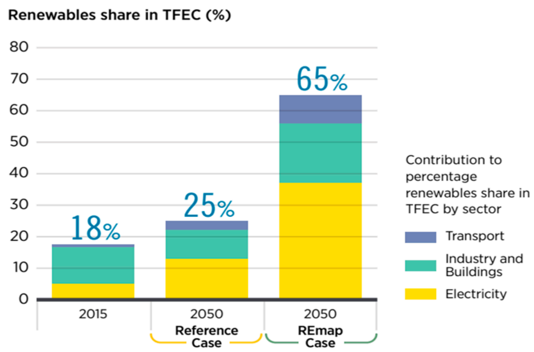

Figure 3. Renewable energy shares in the total final energy consumption [13].

1.3. DS Grid-Integration Challenges

DS Grid-integration challenges can be categorised into technical and non-technical. Technical challenges can be subdivided into operational and non-operational challenges. Operational challenges may be described as those pertaining to the hindrance of accomplishing the PS's main functions of secured and efficient generation, transmission and delivery of quality and reliable power. These may include actions or/and decisions taken timeously by PS operators to assure and maintain satisfactory PS operation. Non-operational challenges may be termed as those related to particularly the planning and the design activities that are initiated to minimize operational challenges. Non-technical challenges are essentially socio-economic and environmental challenges. Only operational challenges will be considered in this review paper. Figure 4 provides a comprehensive and up to date categorization of DG challenges.

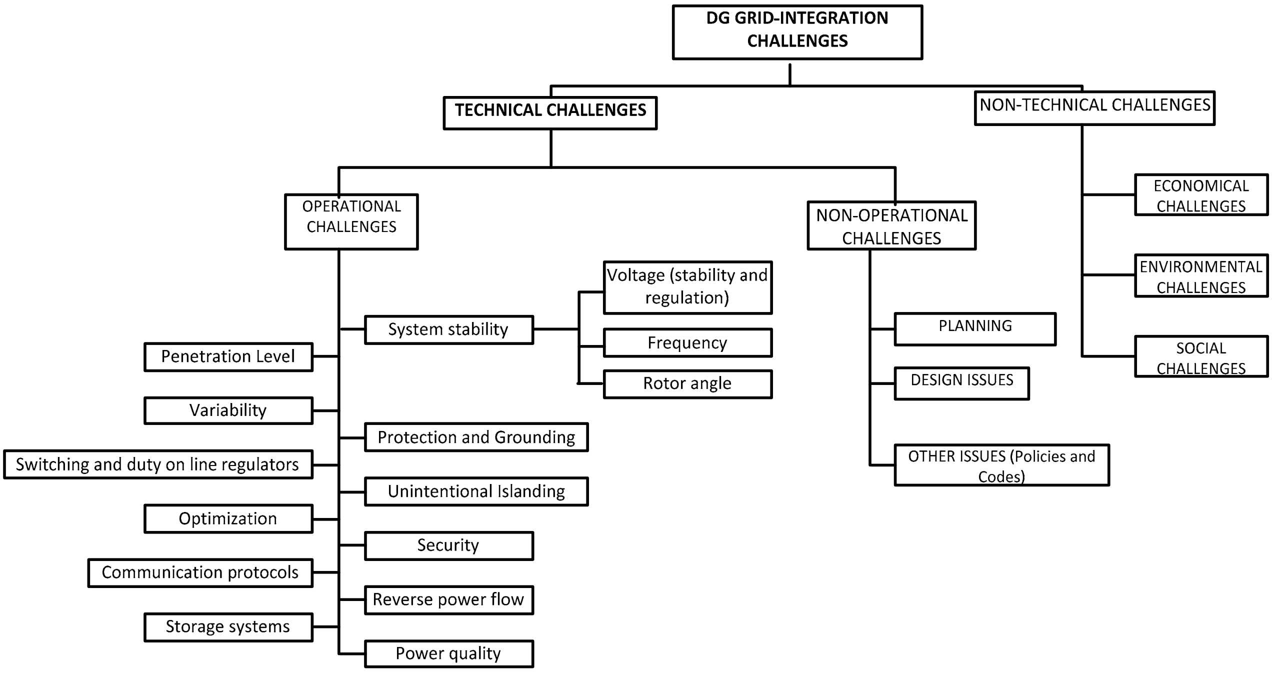

Figure 4. Categorization of DS grid integration challenges.

In order to approach those emerging challenges and address them efficiently, the authors in Ref. [15] suggest that both evolutionary and revolutionary technological changes would be required together with grid-integration technologies and techniques as well as substantial financial resources and strategies. The severity impact of the challenges resides mainly in:

- The difficulty to predict the system behaviour due to the fact that the optimal distribution network solutions must include the types of DG technologies, with their associated intricacies such as climatic conditions dependency and power generation compatibility.
- Higher penetration and inappropriate accommodation of DGs can jeopardise the system's protection and coordination and ultimately lead to system instability and excessive network losses [16,17].
- Energy storage capacity and location [18].
- Load demand scenarios and DR strategies for maximum possible utility and consumers' benefits.

2. Research Methodology and Organization of the Paper

2.1. Paper Methodology

Research data were collected using various search libraries with the major ones including IEEE Xplore, MDPI, Science Direct, Springer Link and Wiley Online Library. Figure 5 presents the summary of the data collection distribution from various sources used with the most relevant information coming from the IEEE Xplore. The category "others" included Elsevier, the National Renewable Energy Laboratory (NREL), Research gate and Google Scholar, particularly by searching up on pre-selected authors from the major libraries mentioned above. Six keywords were used to search for the data, namely: "Distribution systems issues", "Distributed Energy resources: review", "Review on operational issues on DS", "Renewable energy optimization techniques and objectives: review" and "Smart Grids". The search was conducted and finalized using a three-level filtering process for each search library as follows:

- Step 1: Relevance: using the above-mentioned keywords, run the search and obtain journal and conference papers that match the searching keywords. A total of 168 articles deemed to be relevant were collected at this stage.
- Step 2: Year of publication: from previous filter level results, only research papers of the last decade were selected, and 41 papers were excluded from step 1 selection. However, due to their strong relevance and valuable contribution to the topic in discussion, 17 papers out of this selection, published between 1994 and 2011 were rescued from the exclusion [1,2,6,19–28]. Figure 6 provides the collected data breakdown's distribution based on the year of publication.
- Step 3: Titles and abstracts: the last step was concerned with filtering using paper titles and abstracts.

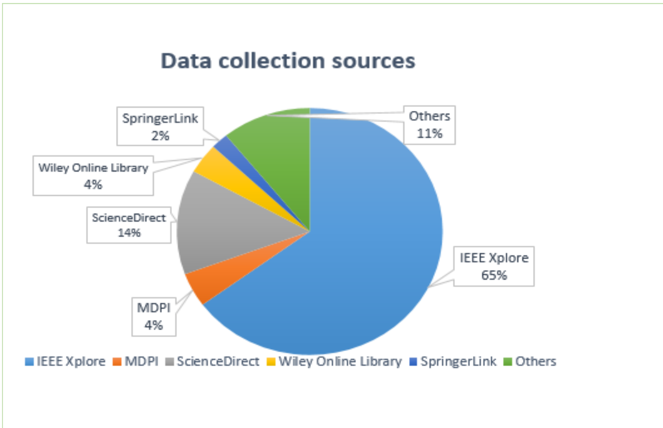

Figure 5. Distribution of collected data with reference to sources used.

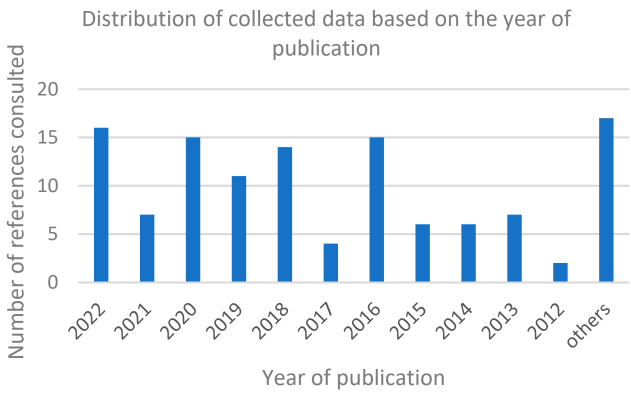

Figure 6. Distribution of collected data based on the year of publication.

2.2. Contributions of the Paper

The prime drive of this paper is to discuss and summarize various reported concerns on DS operational issues due to renewable energy grid integration and available remedies thus far. The main contributions of this article are:

- The paper reviews and presents DG grid integration challenges with regards to techno-economic aspects. The challenges addressed include intermittency and the no-dispatchability of RES, network power quality, stability and reliability, electricity market penetration and (de)regulation.
- Existing solutions and strategies are aggregated, packaged and presented in ready-to-use formats that are simple to refer to. The discussed solutions include DR strategies, charging and discharging techniques of battery energy storage, optimization techniques used for DERs in smart grids, coordination of multiple renewable sources, storage systems and DRs to minimize distribution systems' operational issues.

- The findings of this research paper will assist fellow PS renewable energy scholars and researchers to undertake further investigations and development in the field.

The rest of the paper is structured as follows: Section 3 highlights technical aspects of RE grid integration challenges with emphasis on DS grid integration operational challenges. Section 4 discusses the current status of solution strategies to overcome these challenges while identifying all possible gaps in the implementation of the strategies. Section 5 presents and discusses the conclusions as well as some future research directions that are corollary to the discussions.

3. Highlights of RES Grid-Integration Challenges

3.1. Review of Past Reviews on DS Issues

For more than a decade, DGs grid integration challenges have been the subjects of research surveys from several authors with numerous operational issues substantially reviewed. As earlier as 2009, Basso in Ref. [29] amongst others, documented and evaluated through a National Renewable Energy Laboratory (NREL) report, system impacts of DG penetration into transmission and distribution systems with a focus on renewable distributed resources technologies. The objectives of the report were to identify: (1) critical impact areas on transmission and distribution systems, (2) the best practices studies and challenge mitigation techniques related to the resolution of the system impacts, as well as (3) the then challenges and needs for further development to improve DG grid penetration. In [29], the author suggests that system impacts be categorised under the following headings: voltage regulation, power quality, voltage and system frequency stability, protection coordination, grounding, unintentional DG islanding, special issues related to DGs on secondary distribution network systems and special issues related to RES. Adding to the above categories, Prakash and Darbari in Ref. [30] spotted the development of secured and trusted system as a critical issue and identified the following security critical issues: methodologies to assess the security level of any system and monitoring of the system security including the development of security matrices, implementation of novel techniques for secure data communications, application of middle ware in DS security and applications of web services in security purposes. With solar and wind energy suppliers ramping up their energy capacity, Palmintier et al. [15] identified and reported further emerging challenges of concern, namely reverse power flow, increased duty on line regulators leading to equipment wear and tear, variability due weather uncertainty and capacitor switching. In the last past five years, research and the need for further development to improve DG grid penetration have been focussing on system efficiency, optimal planning and optimal integration. Researchers' attention is being drawn particularly on the following concerns: optimization techniques under various scenarios to enable higher penetration capacity, DSM and DR [31], energy storage systems to improve reliability, communication protocols, and cyber security. There is a general consensus that RES grid integration is an ongoing field for investigation and to respond to the anticipated RER integration challenges highlighted above, PS researchers propose advanced technologies and solution methodologies that will be discussed later in the paper.

The literature review conducted in this paper considered a number of relevant previous review papers that cover specific areas of DS challenges associated with DG grid-integration such as: reviews on DG penetration issues [15,32–38], flexibility issues in DS [10,39,40], protection issues [16,17,41,42], voltage stability and voltage regulation [43–46], uncertainty analysis and assessment [47,48], DR programs and DSM [31,49–53], unintentional islanding [54], cyber security issues [4,30], islanding [54], and vehicle grid system integration and applications [55–57]. Table 2 provides a comprehensive summary of the review papers samples used for the literature review of this paper.

Table 2. Sample review papers considered in the literature review.

Review Aspect	Paper Title	Ref.
Penetration issues	On the Path to Sun Shot: Emerging issues and Challenges in Integrating Solar with the Distribution System	[15]
	Integration of renewable distributed generators into the distribution system: a review	[32]
	Integrating Variable Renewable Energy: Challenges and Solutions	[33]
	Distributed generation: A review of factors that can contribute most to achieve a scenario of DG units embedded in the new distribution networks	[34]
	On the Path to Sun Shot: Emerging issues and Challenges in Integrating High Levels of Solar into the Electrical Generation and Transmission System	[35]
	A critical review of the integration of renewable energy sources with various technologies,	[36]
	Photovoltaic penetration issues and impacts in distribution network—A review	[37]
	Grid Integration Challenges and Solution Strategies for Solar PV Systems: A Review	[38]
Flexibility issues in DS	Research and Practice of Flexibility in Distribution Systems: A Review	[10]
	A review of demand side flexibility potential in Northern Europe	[40]
	Aggregation of Demand-Side Flexibilities: A Comparative Study of Approximation Algorithms	[39]
Wind and hybrid-systems operational issues	Solar–wind hybrid renewable energy system: A review	[58]
	Hybrid renewable energy systems for off-grid electric power: Review of substantial issue	[59]
	Wind Resources and Future Energy Security: Environmental, Social, and Economic Issues,	[60]
Protection issues	Renewable Energy Integration Challenge on Power System Protection and its Mitigation for Reliable Operation	[16]
	Renewable distributed generation: The hidden challenges—A review from protection perspective	[17]
	A comprehensive review on issues, investigations, control and protection trends, technical challenges and future directions for Microgrid technology	[41]
	A review of protection systems for distribution networks embedded with renewable generation	[42]
Voltage stability and voltage regulation	Voltage Stability Analysis with High Distributed Generation (DG) Penetration,	[43]
	A comprehensive review of the voltage stability indices	[44]
	Impact of distributed generation on protection and voltage regulation of distribution systems: A review	[45]
	Grid-connected photovoltaic system in Malaysia: A review on voltage issues,	[46]
DR programs and DSM strategies	Survey on Demand Response Programs in Smart Grids: Pricing Methods and Optimization Algorithms	[31]
	Residential peak electricity demand response—Highlights of some behavioural issues	[49]
	Particle Swarm Optimization in Residential Demand-Side Management: A Review on Scheduling and Control Algorithms for Demand Response Provision	[50]
	Residential Sector Demand Side Management: A Review	[51]
	A Survey of Efficient Demand-Side Management Techniques for the Residential Appliance Scheduling Problem in Smart Homes	[52]
	A review on price-driven residential demand response,	[53]

Table 2. *Cont.*

Review Aspect	Paper Title	Ref.
Vehicles grid system integration and applications	Comprehensive review & impact analysis of integrating projected electric vehicle charging load to the existing low voltage distribution system	[56]
	A comprehensive analysis of Vehicle to Grid (V2G) systems and scholarly literature on the application of such systems,	[55]
	A review on the state-of-the-art technologies of electric vehicle, its impacts and prospects	[57]
Unintentional Islanding	A review on islanding operation and control for distribution network connected with small hydro power plant	[54]

3.2. Impacts of Operational Challenges

The power output of most dominant DG resources is dependent on weather conditions, making these resources characterized by a variable generation property [38,61] that constitutes its own challenge. In traditional grids, operational uncertainties usually result from the demand side only. Distributed energy sources (DES) grid integration introduces new challenges, as the operational uncertainties emanate from both the demand and the generation sides [38] and have consequently significant impact on optimal planning of DGs [62]. Beside the technical considerations, Liu et. al. in Ref. [63] warn that these uncertainties can influence electricity users' economic benefits. Shafiullah et al. [38] note that accurate prediction of PV power for instance, has become an essential task for safe and stable PS operation and the prediction can focus on energy output or rate of change. The prediction types depend on the tools and information available from the meteorological stations. Ref. [38] also present the prediction models that were developed by [64,65]. Recent reported models for the prediction of power output are based on machine learning techniques as presented in Refs. [66–68].

The following challenges have been highlighted and dealt with by several researchers worldwide:

- Design and sizing of the system [5,15,32,33,47,69–74];
- Power balancing and voltage stability [7,43,69,71,75–78];
- Optimal energy management [11,79–94];
- Optimal DG allocation and penetration level [8,9,16,34,38,69,71,90,95–98];
- System cost minimization [22,82,99];
- Energy storage: operation strategies, coordination, optimization;
- Optimal coordination of various DERs [62,80,92,100–103];
- Localized overloading due to electric vehicle chargers [55,56,104].

Table 3 provides some references addressing design and integration, power quality and voltage stability, protection coordination, optimal distributed generation allocation, level of penetration as well as energy storage issues.

Table 3. Sample of some references and issues that they are addressing.

Ref.	Design and Integration of the System	Power Quality and Voltage Stability	Protection Coordination	Optimal DG Allocation	Penetration	Energy Storage
[5]	✓				✓	
[43]	✓	✓			✓	
[69]	✓				✓	
[98]	✓				✓	
[33]	✓					
[7]		✓		✓		
[8]				✓	✓	
[16]		✓	✓	✓		

Table 3. *Cont.*

Ref.	Design and Integration of the System	Power Quality and Voltage Stability	Protection Coordination	Optimal DG Allocation	Penetration	Energy Storage
[38]				✓		
[45]		✓	✓	✓		✓
[71]		✓		✓		✓
[105]		✓		✓		✓
[106]	✓					✓

4. Solutions Strategies for DS Grid Integration

To overcome the above challenges, researchers are exploring solutions that will provide satisfactory results to the power system network as a whole, as well as to procure benefits to both the utilities and the customers. The solutions that have been provided are summarized below.

4.1. Optimal Integration and Planning of Renewable Distributed Generation

DG optimal integration can improve network performance [103]. The optimal integration of DGs can be achieved through several strategies, the most popular one being through use of mathematical optimization models. Ehsan and Yang [62] have provided a good account of analytical techniques that are used for optimal integration and planning of renewable DG in the power distribution network. The strategies can, in a particular context and environment, invariably be used to address most of the challenges that have been mentioned in the previous section.

- The following, researched and presented by Georgilakis et al. in Ref. [107], are the mathematical formulations components for optimization approaches: a general problem statement, problem objectives whether single or multi, number of DGs and type of DG technology and a number of constraints to be considered.
- This is in the agreement that indeed, as mentioned by [32,94,95], the performance benefits depend mainly on the optimal sizing and location of the DG units, the DS configuration and the types of DG technologies used for conversion of energy. In Ref. [76], Esmaili was one of the earliest researchers to propose a multi-objective framework for placing and sizing DG units with the combination of the number of DGs, voltage stability margin and minimization of power loss into one objective function.
- In Ref. [108], the authors reviewed probabilistic optimization techniques (POT) in Smart Power Systems and noted that in order to account for uncertainties in optimization processes, stochastic optimization is essential. From their review, probabilistic optimization techniques were classified into stochastic optimization (SO), robust optimization (RO), distributionally robust optimization (DRO) and chance constraints optimization (CCO), each of which having their own advantages and drawbacks over the others, with the common drawback to all being their high computational requirements. Riaz et. al. [108] further proposed that the most advanced and less costly technique is the robust optimization in which a deterministic, set-based uncertainty model is used instead of a stochastic one. The authors suggest that POTs must be used in combination in order to deal with new challenges to achieve prolific outcomes.
- The authors in [92,101–103,109–112] have worked on various aspects related to DG grid integration optimization. The solutions proposed include the following benefits: more energy savings, improvement of voltage profile, reduced purchased power from the DGs, increased sold power to the distributed grid, decreased non-supply load, reduced overall cost of smart grid and mitigation of fault severity.
- Fast dispatch is one of the techniques that helps manage the variability of renewable generation because it reduces the need for regulating resources, improves efficiency and provides access to a broader set of resources to balance the system [33].

With regards to planning, to handle the high complexity of the investment planning problem for instance, Ref. [102] used a bi-level optimization framework that maximizes the net present value (NPV). Level-1 determines the optimal sizing of BESS in the presence of high PV penetration with the aim of minimizing the net present cost (NPC). The optimal BESS power dispatch in coordination with the DR aggregator is obtained in level-2, aiming to minimize NPC for voltage deviation penalty and PS losses with the scheduling of BESS and DR only [102]. In Ref. [61], a method to determine the optimal location, power and energy capacity of storage by creating an independent objective function for the voltage profile and power losses was proposed. The authors used the symbiotic organism search algorithm (SOSA) to solve the optimization problem with the following objectives: improvement of voltage profile, loss reduction, network reliability and minimization of storage costs including investment, operation and maintenance costs. SOSA has the advantage over other conventional algorithm (PSO and GA) of having specific adjusting parameters allowing for the conversion rate increase.

4.2. DER Coordination

Sharma et al. in [80] investigated the coordination of multiple DERs to address the techno-economic aspects of distribution network operation. The study aimed to find optimal dispatches of BESS in coordination with DR for wind generation and shunt capacitor with the target of minimizing distribution power loss. In [103], the authors developed a bi-level optimization framework for impact analysis of DR on PV and BESS accommodation in DS. The study was motivated by the undergoing intensive research on responsive loads driven by dynamic pricing that have shown benefits for utilities and consumers by shifting the demand peak to off-peak periods by utilizing renewable energy.

Achieving optimal integration of DGs is a complex problem involving many components, variables and constraints, network status, load dynamics and faults events, protection schemes, weather conditions and consumers' behaviour. Optimal integration requires the minimization as much as possible of operational issues. This is largely achievable through the coordination of multiple DERs. The following types of coordination have been under research with progressive results to achieve efficient, reliable and economical use of grid-integrated renewable energy resources:

- Coordination of DGs, BESS and DR for multi optimization of distribution networks [80,102];
- Energy scheduling with BESS cost [87];
- Energy management with electricity price;
- Accommodation of PV, DR and BESS [103];
- Solar PV with BESS under uncertain environment [112];
- Investment planning of DG resources with DR [102];
- DR analysis for optimal allocation of wind and solar [90];
- Optimal sizing of PV/wind and hybrid considering DSM [113];
- DR trends: users, network services, markets, and DERs [114];
- DR and intermittent RERs [115];
- Price-driven DR [53];
- Household appliances and DR [116];
- Joint allocation and operational management of DG and BESS in presence of DR [92];
- Pricing schemes, optimization objectives and solution methodologies of DSM [11];
- DR: Pricing, optimization and appliance scheduling [117];
- DSM model and optimization;
- Optimal planning and investment benefits of shared BESS;
- DGs, power losses and voltage stability.

4.3. Energy Storage Systems and Complementary Technologies

Kucur et al. [18] examined worldwide energy storage applications, their best location, applied technologies, total energy and power capacity and quality. Pumped storage are the most common type of grid-scale energy storage, but lead acid and lithium ion batteries are the most prominent for solar PV systems [18]. Although they have relatively high capital costs as indicated amongst other drawbacks by Liu et al. in Ref. [72], energy storage systems are essential technologies as they provide support to overcome the challenge of balancing supply and demand [18] and to cope with the intermittent renewable generation as well as to reduce the user's electricity purchase cost [63].

Installing BESS at any location with any random and non-optimum size can lead to high costs [61]. Using a storage device in the operation indices depends more on the installation location than the storage capacity. The authors in Ref. [118] have assessed the simultaneous impact of BESS, controllable load and network reconfiguration on contemporary distribution networks under uncertainties. The multi-constraint complex optimization problem was solved using an improved water evaporation optimization algorithm and the authors found that the coordination strategy reduced network loss while improving the voltage profile of the systems. The impact of multiple BESS strategies on energy loss of ADNs was investigated by Sharma et al. in [110]. With regards to the function of regulating the voltage on the utility side, Gamage et al. in Ref. [105] proposed an approach to integrate BESS to curb grid voltage violations.

- Ref. [63] proposed an approach of optimal planning of shared energy storage based on cost–benefit analysis to minimize the electricity procurement of retailers. They found that ES can effectively reduce the cost of retailers and high matching degree can be used as the selection criterion to obtain greater benefits from the shared ES [63].
- Ref. [72] proposed a comprehensive optimal allocation model of BESS considering operation strategy with the optimal capacity problem solved by cost–benefit analysis taking into account the reliability improvement benefits of BESS.
- The authors in Ref. [72] proposed system reliability improvements with BESS in planning operation strategies. The optimal BESS capacity and sizing problem was solved by cost–benefit analysis. The authors concluded that from an economic point of view, the distributed mode is preferable to centralized modes and the benefits of BESS can be improved by increasing the peak–valley difference of electricity price within a certain range.
- Ref. [72] was one of the earlier studies that proposed a comprehensive optimal allocation model of BESS that considered reliability benefits.

Table 4 presents a useful summary of important contribution, challenges, methodologies used and potential solutions to DG.

Table 4. Summary of major contributions, challenges, methodologies and potential solutions.

Ref.	Challenges or Issues	Solution Methodology	Research Objectives	Constraints/Objective Function	Paper Contribution
[90]	▪ Optimal accommodation in coordination with DR ▪ Impact on planning of wind-based and solar-based DGs in DS	MISOCP	▪ Energy savings ▪ Improvement of voltage profile	▪ Energy losses ▪ Minimum voltage ▪ Average voltage deviation ▪ DG penetration level ▪ Peak demand	▪ Integrating DR with planning of DGs leads to more energy savings and improvement of voltage profile
[16]	▪ Secure protection for DS network ▪ Protection blinding issue	Adaptive Over Current Protection (AOCP)		▪ High DER penetration ▪ Grid connected and islanded modes	▪ Provided an alternative protection scheme working regardless connection to grid or islanding condition,

Table 4. *Cont.*

Ref.	Challenges or Issues	Solution Methodology	Research Objectives	Constraints/Objective Function	Paper Contribution
[119]	▪ PV boosting development ▪ LSPV modelling and simulation techniques ▪ LSPV integration impacts on grid static and dynamic characteristics ▪ Key techniques for improving LSPV transmission and consumption		▪ RE integration ▪ Large-scale PV development in China		▪ Review of large scale PV integration (LSPV) ▪ Recommendations for further research with regards to modelling and simulations, system integration and power generation delivery and co consumption
[115]	▪ Reduce overall cost of smart grid and maximize reliability	▪ PSO	▪ Optimal size of units for the smart grid	▪ Cooling and heating management ▪ Impact on smart grid cost	▪ Power consumption of heating and cooling systems resulted in decreasing the size of DGs ▪ Reduced the purchase power from the DGs ▪ Increased the sold power to distributed grid ▪ Decreased non-supply loads ▪ Reduced the overall cost of smart grids
[74]	▪ Mitigation of fault severity brought by DG penetration ▪ Causes protection devices not to operate properly	▪ Fault at various locations ▪ Balanced three-phase faults are used	▪ Protection planning and coordination without and in the presence of DGs	▪ Voltage constraint ▪ Thermal limits	▪ Addressed challenges associated with the operation of DS in both normal and contingency operation states
[86]	▪ Optimal use of DERs	▪ MPSO	▪ Minimization of operating cost of a microgrid	▪ Optimization problem of a community micro-grid	▪ Problem with optimization of a community micro-grid ▪ However, solutions had significant deviations due to prediction errors
[87]	▪ Overall Minigrid cost reduction	▪ PSO (for model optimization) and Rainflow (for battery degradation cost)	▪ Electricity cost management through efficient control of BESS	▪ Battery degradation cost ▪ Dynamic electricity price	▪ Proposed a day-ahead energy management for a community micro grid with consideration of battery degradation costs ▪ 40% cost reduction compared to the baseline approach

Table 4. *Cont.*

Ref.	Challenges or Issues	Solution Methodology	Research Objectives	Constraints/Objective Function	Paper Contribution
[92]	▪ Energy losses ▪ Voltage deviation (stability)	▪ Mixed integer second order conic programming (MISOCP)	▪ To propose framework for joint allocation and operational management of wind DG and BESS ▪ Optimally allocate wind-based DG and BESS	▪ Power flow ▪ Wind-based DG constraints ▪ BESS constraints ▪ Demand response constraint	▪ Simultaneous allocation and operation management of wind-based DG and BESS in distribution system considering DR ▪ Optimal sizing and siting of wind DG and BESS along with DR participation leads to significant energy savings and improvement of power quality ▪ When DR participation rate increased, BESS capacity decreased
[120]	▪ Determination of dynamic electric energy retail pricing tariffs	▪ Statistical analysis	▪ Improve the performance of demand response techniques	▪ Minimum power demand ▪ Load variation	▪ Novel quantitative measure of the load profile that accurately reflected the overall generation expansion planning and utilization costs ▪ Peak-to-average ratio (PAR) did not reflect the load characteristics
[53]	▪ Price-driven demand response (PDDR) to affect customers' consumption (including critical peak pricing, TOU pricing, real-time pricing		▪ Evaluation of advantages and disadvantages of PDDR		▪ Review of three different PDDR programs at residential sector ▪ TOU ▪ CPP ▪ RTP
[51]	▪ Lack of informed decision from both the supplier and the consumer		▪ DSM to redesign the load profile and to decrease the peak load demand		▪ Review of DSM strategies with both DR and energy efficiency policies
[110]		▪ Generic Algorithm (GA)	▪ Optimal operation strategies ▪ Validation of economic benefit	▪ Node voltage limit ▪ Feeder current limit ▪ Nodal power balance	▪ Optimal operation of BESS can reduce energy loss and increase economic benefits of the DS

Table 4. *Cont.*

Ref.	Challenges or Issues	Solution Methodology	Research Objectives	Constraints/Objective Function	Paper Contribution
[103]	▪ Optimal integration of emerging DERs	▪ Bi-level GA using Matlab		▪ PV generation limits ▪ BESS constraints ▪ Feeder thermal limit constraints ▪ Power balance constraints	▪ DGs were effective in annual energy loss reduction ▪ BESSS facilitated higher DG penetration and levelled the load profile ▪ DR bridged the gap between peak and valley demands and therefore distresses to the system
[118]		▪ Innovative Water Evaporation (IWEO) algorithm	▪ Optimal coordination of controllable load scheduling, BESS and uncertain wind power	▪ Nodal power balance ▪ Feeder thermal limits ▪ Controllable load management ▪ Network configuration	▪ Two-stage framework was developed to coordinate the generation of DGs, scheduling of BESSs, optimal management of controllable load
[105]	▪ Fluctuation of grid voltage	▪ Power flow simulation			▪ Incorporation of BESS can mitigate voltage violation ▪ More effective in rural distribution feeder suggesting when the line impedance is high
[80]		▪ Non-sorted generic algorithm (NSGA-II) ▪ Technique for order of preference by similarity to ideal solution (TOPSIS)	▪ Optimal dispatches of BESS ▪ Minimize distribution power loss and grid demand cost	▪ Nodal voltage limit ▪ Power loss minimization ▪ Grid demand cost minimization ▪ Nodal power balance ▪ Feeder thermal limits	▪ Optimal coordination of wind power, BESS, SC and TOU-DR significantly reduced the network losses and grid demand consumption cost
[76]	▪ To place DG units at more efficient buses rather than end buses of radial links usually used for voltage stability improvement	▪ Non-Linear Programming (NLP) ▪ Fuzzification applied to objective functions	▪ Optimal sizing and location of DG units	▪ Number of DGs ▪ Power loss minimization ▪ Maximize voltage stability margin ▪ Branch and voltage limits	▪ Modelled all types of DGs ▪ Employed adaptive reactive limits rather than fixed limits ▪ New technique to formulate the number of DGs without converting the NLP problem into mixed-integer NLP ▪ Minimization of the number of DG units led to placement of these units at more efficient buses rather than end buses of radial link

Table 4. *Cont.*

Ref.	Challenges or Issues	Solution Methodology	Research Objectives	Constraints/Objective Function	Paper Contribution
[102]	▪ Simultaneous consideration of cost of energy purchased from the grid, energy losses, emission penalty cost, demand deviation penalty, operation and maintenance cost for NPV benefits	▪ Complex mixed-integer, non-linear and non-convex optimization techniques ▪ Bi-level optimization problem (BLOP)	▪ Multilayer DS and BESS investment planning with coordination of DR ▪ The coordination aimed to maximize Net Present Value (NPV) profit	▪ PV generation limits ▪ BESS capacity limits ▪ Power dispatch and SOC limits ▪ DR constraints ▪ Thermal feeder limits ▪ Power balance constraints ▪ Cost of energy purchased from the grid ▪ Energy losses ▪ Emission penalty cost ▪ Demand deviation penalty ▪ Operation and maintenance cost	▪ Impact of DR on investment planning of DG and BESS ▪ Simultaneous consideration of cost of energy purchased from the grid, energy losses, emission penalty cost, demand deviation penalty, operation and maintenance cost for NPV benefits ▪ Higher NPV benefits ▪ Analysed impact of DR on payback period: payback within 9 of 20 years of planning was significant compared to non-DR-based investment planning ▪ Other technical benefits
[32]	▪ Optimal sizing, siting and configuration of DGs		▪ Review on technical benefits of renewable DG ▪ Review current status of REN		▪ Significant roles that renewable DGs can play in technical, economic and environmental operation
[72]		▪ Intelligent Single Particle Optimiser (ISPO) ▪ Sequential Monte Carlo simulation method		▪ Operation strategy of BESS (power and time periods of charging and discharging) ▪ Reliability improvement benefits of BESS ▪ Optimal planning model of BESS	▪ Comprehensive optimal allocation model of BESS considering operation strategy ▪ Numerical method based on expectation for the calculation of system reliability improvement with BESS in planning was proposed ▪ Optimal BESS capacity and sizing problems were (simultaneously?) solved by cost–benefit analyses
[62]			▪ Optimal planning of DGs ▪ Power quality, voltage stability, power loss, reliability and profitability		▪ Conventional and metaheuristic techniques ▪ Metaheuristics algorithms were popular choice because of their flexibility in multi-objective planning problems

Table 4. *Cont.*

Ref.	Challenges or Issues	Solution Methodology	Research Objectives	Constraints/Objective Function	Paper Contribution
[106]	▪ Determination of optimal location and sizes		▪ Optimal DG placement and sizing ▪ Models and solutions ▪ Classify current and future research trends in this field	▪ DG capacity constraints ▪ Operating constraints ▪ Investment constraints	
[63]			▪ Cope with intermittency and reduce customer electricity purchase cost		▪ Fluctuation of electricity prices and the uncertainty of RE resources' output did not influence users' economic benefits ▪ Shared energy storage (ES) system among multiple electricity retailers showed more benefit rather than the separately configured ES

5. Further Research Priorities and Conclusions

5.1. Further Research Priorities

From this review study, the following concerns have not been appropriately and exhaustively attended to and therefore still require researchers' attention:

- All-in-One multi-objective DER optimal planning solutions that include the coordination of various variables such as the type of DG technologies, the types of energy storage integration, DSM mechanisms and different DR strategies, for maximum benefits both for the utility and consumers have not yet been sufficiently researched.
- Further investigations are needed in establishing optimization techniques using hybrid techniques that combine analytical, metaheuristic and computational methods to achieve better results.
- The use of optimization algorithms, ensemble methods and weather forecasting to develop models that can predict renewable energy power output considering weather conditions and seasonal variation still need attention and focus from researchers.
- Development of robust models to quantify the impact of uncertainties related to intermittency of renewable DGs. There is a need to gather resources and tools for weather condition predictions.

5.2. Conclusions

The transformation of PS around the world is effective and largely impacted by a rapid growth of various renewable energy grid integration thus affecting the control and operation of contemporary DS which are becoming more and more active network systems. Supporting and remedial actions are required and should be planned accordingly. This paper presents various operational and technical challenges associated with DG integration into DS. It was shown that the challenges of different natures at different levels of the PS are usually addressed individually, prompting that a holistic approach be considered when addressing them. Power quality, voltage stability, PS reliability, loss minimization, cost–benefits and so many other objectives can be achieved with optimal integration and appropriate planning of DGs. The DG grid integration problem is a multi-objective and hence needs advance multi-objective algorithms to address more than one challenge simultaneously. In order to reduce the variability and increase predictability, robust models need to be designed to include accurate forecasting methods, reliable data collection and safe communication to cater to RE technologies' uncertainties and intermittent nature. Further energy storage and demand side management can play a major role in supplying quality and reliable power to the customers and at the same time reduce the burden on DGs and their intricacies such as variability.

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References

1. Dobson, I.; Green, S.; Rajaraman, R.; DeMarco, C.; Alvarado, F.; Galavic, M.; Zang, J.; Zimmerman, R. *Electric Power Transfer Capability: Concepts, Applications, Sensitivity and Uncertainty*; University of Wisconsin–Madison: Madison, WI, USA, 2001.
2. Machowski, J.; Bialek, J.W.; Bumby, J.R. *Power System Dynamics: Stability and Control*, 2nd ed.; Sons, J.W., Ed.; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2008.
3. Gafaro, F.; Portugal, I. Planning the Operability of Power Systems–Overcoming Technical and Operational Bottlenecks. Available online: https://www.irena.org/-/media/Files/IRENA/Agency/Events/2017/Jan/17/IRENA-WFES-Scaling-up-VRE---Operation-Planning---Final.pdf?la=en&hash=DA778DAF2644A2D6DBC70665B109E6B3AACA6673 (accessed on 17 January 2023).
4. Berger, L.T.; Iniewski, K. *Smart Grid: Applications, Communications and Security*; John Wiley & Sons: Hoboken, NJ, USA, 2012.
5. Banerjee, S.; Mesram, A.; Swamy, N.K. Integration of Renewable Energy Sources in Smart Grid. *Int. J. Sci. Res.* **2015**, *4*, 247–250.
6. Freris, L.; Infield, D.G. *Renewable Energy in Power Systems*; John Wiley & Sons Ltd: Hoboken, NJ, USA, 2008.
7. Loji, K.; Davidson, I.E.; Tiako, R. Voltage Profile and Power Losses Analysis on a Modified IEEE 9-Bus System with PV Penetration at the Distributed Ends. In Proceedings of the Southern African Universities Power Engineering Conference/Robotics and Mechatronics/Pattern Recognition Association of South Africa (SAUPEC/RobMech/PRASA), Bloemfontein, South Africa, 27–29 January 2019.
8. Kumar, A.K.; Selvan, M.P.; Rajapandiyan, K. Dynamic Grid Support System for Mitigation of Impact of High Penetration Solar PV into Grid. In Proceedings of the 2017th International Conference on Power Systems (ICPS), Pune, India, 21–23 December 2017.
9. Von Appen, J.; Braun, M.; Stetz, T.; Diwold, K.; Geibel, D. Time in the Sun: The Challenge of High PV Penetration in the German Electric Grid. *IEEE Power Energy Mag.* **2013**, *11*, 55–64. [CrossRef]
10. Dalhues, S.; Zhou, Y.; Pohl, O.; Rewald, F.; Erlemeyer, F.; Schmid, D.; Zwartscholten, J.; Hagemann, Z.; Wagner, C.; Gonzalez, M.D.; et al. Research and Practice of Flexibility in Distribution Systems: A Review. *CSEE J. Power Energy Syst.* **2019**, *5*, 285–294.
11. Ahmad, S.; Ahmad, A.; Naeem, M.; Ejaz, W.; Kim, H.S. A Compedium of Performance Metrics, Pricing Schemes, Optimization objectives and Solution Methodologies of Demand Side Management for the Smart Grid. *Energies* **2018**, *11*, 2801. [CrossRef]
12. US Energy Information Administration. Energy Sources/Activity. Available online: https://www.eia.gov/electricity/reports.php#/T194 (accessed on 22 December 2022).
13. IRENA(2018). *Global Energy Transformation: A Roadmap to 2050*; International Renewable Energy Agency (IRENA): Masdar City, Abu Dhabi, 2018.
14. Uluski, R.; Borlase, S. Next Generation Distribution Management. *Power Ind. 2022 Trends Predict.* **2022**, *2022*.
15. Palmintier, B.; Broderick, R.; Mather, B.; Coddington, M.; Baker, K.; Ding, F.; Reno, M.; Lave, M.; Bharatkumar, A. *On the Path to SunShot: Emerging Issues and Challenges in Integrating Solar with the Distribution System*; NREL/TP-5D00-65331; National Renewable Energy Laboratories: Golden, CO, USA, 2016.
16. Altaf, M.W.; Arif, M.T.; Saha, S.; Islam, N.; Haque, M.E.; Oo, A. Renewable Energy Integration Challenge on Power System Protection and its Mitigation for Reliable Operation. In Proceedings of the IECON 2020 The 46th Annual Conference of the IEEE Industrial Electronics Society, Singapore, 18–21 October 2020; pp. 1917–1922.
17. Manditereza, P.T.; Bansal, R. Renewable distributed generation: The hidden challenges-A review from protection perspective. *Renew. Sustain. Energy Rev.* **2016**, *58*, 1457–1465. [CrossRef]
18. Kucur, G.; Tur, M.R.; Bayindir, R.; Shabinzadeh, H.; Gharehhpetian. A review of Emerging Cutting-Edge Energy Storage Technologies for Smart Grids Purposes. In Proceedings of the 2022 9th Iranian Conference on Renewable Energy & Disitributed Generation (ICREDG), Mashhad, Iran, 23–24 February 2022.

19. CIGRE, W.G. *37-23, Impact of Increasing Contribution of Dispersed Generation on Power System: Final Report*; Electra: Ramat Gan, Israel, 1998.
20. Barker, P.P.; De Mello, R.W. Determining the Impact of Distributed Generation on Power Systems. Part-1. radial Distribution systems. In Proceedings of the IEEE PES Summer Meeting, Seatle, DC, USA, 16–20 July 2000; pp. 1645–1656.
21. Cossent, R.; Gómez, T.; Frías, P. Towards a future with large penetration of distributed generation: Is the current regulation of electricity distribution ready? Regulatory recommendations under a European perspective. *Energy Policy* **2009**, *37*, 1145–1155. [CrossRef]
22. Feinstein, C.D.; Orans, R.; Chapel, S.W. THE DISTRIBUTED UTILITY: A New Electric Utility Planning and Pricing Paradigm. *Annu. Rev. Energy Environ.* **1997**, *22*, 155–185. [CrossRef]
23. Kundur, P.; Paserba, J.; Ajjarapu, V.; Andersson, G.; Bose, A.; Canizares, C.; Hatziargyriou, N.; Hill, D.; Stankovic, A.; Taylor, C.; et al. Definition and Classification of Power System Stability-IEEE/CIGRE Joint Task Force on Stability Terms and Definitions. *IEEE Trans. Power Syst.* **2004**, *19*, 1387–1401.
24. Kundur, P. *Power Ssytem Stability and Control*; McGraw-Hill: New York, NY, USA, 1994.
25. Mangoyana, R.B.; Smith, T.F. Decentralised bioenergy systems: A review of opportunities and threats. *Energy Policy* **2011**, *39*, 1286–1295. [CrossRef]
26. Reza, M.; Schavemaker, P.H.; Slootweg, J.G.; Van Der Sluis, S.L. Impacts of Distributed Generation Penetration Levels on Power Systems Stability. *IEEE PES Gen. Meet.* **2004**, *2*, 2150–2155.
27. Slootweg, J.G.; Kling, W.L. Impacts of Distributed Generation on Power system Transient Stability. *IEEE PES Gen. Meet.* **2002**, *2*, 862–867.
28. Vournas, C.D.; Sauer, P.W.; Pai, M.A. Relashionship Between Voltage and Angle Stability of Power Systems. *Int. J. Electr. Power Energy Syst.* **1996**, *18*, 493–500. [CrossRef]
29. Basso, T.S. *System Impacts from Interconnection of Distributed Resources: Current Status and Identification of Needs for Further Development*; NREL/TP-550-44727 National Renewable Energy Laboratory NREL: Oak Ridge, TN, USA, 2009.
30. Prakash, V.; Darbari, M. A Review on Security Issues in distributed Systems. *Int. J. Sci. Eng. Res.* **2012**, *3*, 1–5.
31. Vardakas, J.S.; Zorba, N.; Verikoukis, C.V. Survey on Demand Response Programs in Smart Grids: Pricing Methods and Optimization Algorithms. *IEEE Commun. Surv. Tutor.* **2015**, *17*, 152–178. [CrossRef]
32. Adefarati, T.; Bansal, R.C. Integration of renewable distributed generators into the distribution system: A review. *IET Renew. Power Gener. (Wiley-Blackwell)* **2016**, *10*, 873–884. [CrossRef]
33. Bird, L.; Milligan, M.; Lew, D. *Integrating Variable Renewable Energy: Challenges and Solutions*; National Renewable Energy Laboratory: Golden, CO, USA, 2013.
34. Colmenar-Santos, A.; Reino-Rio, C.; Borge-Diez, D.; Collado-Fernández, E. Distributed generation: A review of factors that can contribute most to achieve a scenario of DG units embedded in the new distribution networks. *Renew. Sustain. Energy Rev.* **2016**, *59*, 1130–1148. [CrossRef]
35. Denholm, P.; Clark, K.; O'Connell, M. *On the Path to SunShot: Emerging Issues and Challenges in Integrating High Levels of Solar into the Electrical Generation and Transmission System*; NREL08563; National Renewable Energy La: Golden, CO, USA, 2016.
36. Erdiwansyah, E.; Mahidin; Husin, H.; Nasaruddin, N.; Zaki, M.; Muhibbuddin. A critical review of the integration of renewable energy sources with various technologies. *Prot. Control Mod. Power Syst.* **2021**, *6*, 1–18. [CrossRef]
37. Karimi, M.; Mokhlis, H.; Naidu, K.; Uddin, S.; Bakar, A.H.A. Photovoltaic penetration issues and impacts in distribution network–A review. *Renew. Sustain. Energy Rev.* **2016**, *53*, 594–605. [CrossRef]
38. Shafiullah, M.; Ahmed, S.D.; Al-Sulaiman, F.A. Grid Integration Challenges and Solution Strategies for Solar PV Systems: A Review. *IEEE Access* **2022**, *10*, 52233–52257. [CrossRef]
39. Öztürk, E.; Rheinberger, K.; Faulwasser, T.; Worthmann, K.; Preißinger, M. Aggregation of Demand-Side Flexibilities: A Comparative Study of Approximation Algorithms. *Energies* **2022**, *15*, 2501. [CrossRef]
40. Söder, L.; Lund, P.D.; Koduvere, H.; Bolkesjø, T.F.; Rossebø, G.H.; Rosenlund-Soysal, E.; Skytte, K.; Katz, J.; Blumberga, D. A review of demand side flexibility potential in Northern Europe. *Renew. Sustain. Energy Rev.* **2018**, *91*, 654–664. [CrossRef]
41. Choudhury, S. A comprehensive review on issues, investigations, control and protection trends, technical challenges and future directions for Microgrid technology. *Int. Trans. Electr. Energy Syst.* **2020**, *30*, 1–16. [CrossRef]
42. Kennedy, J.; Ciufo, P.; Agalgaonkar, A. A review of protection systems for distribution networks embedded with renewable generation. *Renew. Sustain. Energy Rev.* **2016**, *58*, 1308–1317. [CrossRef]
43. Al-Abri, R. Voltage Stability Analysis with High Distributed Generation (DG) Penetration. University of Waterloo: Waterloo, ON, USA, 2012.
44. Modarresi, J.; Gholipour, E.; Khodabakhshian, A. A comprehensive review of the voltage stability indices. *Renew. Sustain. Energy Rev.* **2016**, *63*, 1–12. [CrossRef]
45. Razavi, S.-E.; Rahimi, E.; Javadi, M.S.; Nezhad, A.E.; Lotfi, M.; Shafie-khah, M.; Catalão, J.P.S. Impact of distributed generation on protection and voltage regulation of distribution systems: A review. *Renew. Sustain. Energy Rev.* **2019**, *105*, 157–167. [CrossRef]
46. Wong, J.; Lim, Y.S.; Tang, J.H.; Morris, E. Grid-connected photovoltaic system in Malaysia: A review on voltage issues. *Renew. Sustain. Energy Rev.* **2014**, *29*, 535–545. [CrossRef]
47. Gensler, A.; Sick, B.; Vogt, S. A review of uncertainty representations and metaverification of uncertainty assessment techniques for renewable energies. *Renew. Sustain. Energy Rev.* **2018**, *96*, 352–379. [CrossRef]

48. Tian, W.; Heo, Y.; de Wilde, P.; Li, Z.; Yan, D.; Park, C.S.; Feng, X.; Augenbroe, G. A review of uncertainty analysis in building energy assessment. *Renew. Sustain. Energy Rev.* **2018**, *93*, 285–301. [CrossRef]
49. Gyamfi, S.; Krumdieck, S.; Urmee, T. Residential peak electricity demand response—Highlights of some behavioural issues. *Renew. Sustain. Energy Rev.* **2013**, *25*, 71–77. [CrossRef]
50. Menos-Aikateriniadis, C.; Lamprinos, I.; Georgilakis, P.S. Particle Swarm Optimization in Residential Demand-Side Management: A Review on Scheduling and Control Algorithms for Demand Response Provision. *Energies* **2022**, *15*, 2211–2236. [CrossRef]
51. Panda, S.; Rout, P.K.; Sahu, B.K. Residential Sector Demand Side Management: A Review. In Proceedings of the 2021 1st Odisha International Conference on Electrical Power Engineering, Communication and Computing Technology (ODICON), Bhubaneswar, India, 8–9 January 2021; pp. 1–6.
52. Shewale, A.; Mokhade, A.; Funde, N.; Bokde, N.D. A Survey of Efficient Demand-Side Management Techniques for the Residential Appliance Scheduling Problem in Smart Homes. *Energies* **2022**, *15*, 2863–2896. [CrossRef]
53. Yan, X.; Ozturk, Y.; Hu, Z.; Song, Y. A review on price-driven residential demand response. *Renew. Dustainable Energy Rev.* **2018**, *96*, 411–419. [CrossRef]
54. Mohamad, H.; Mokhlis, H.; Bakar, A.H.A.; Ping, H.W. A review on islanding operation and control for distribution network connected with small hydro power plant. *Renew. Sustain. Energy Rev.* **2011**, *15*, 3952–3962. [CrossRef]
55. Bibak, B.; Tekiner-Moğulkoç, H. A comprehensive analysis of Vehicle to Grid (V2G) systems and scholarly literature on the application of such systems. *Renew. Energy Focus* **2021**, *36*, 1–20. [CrossRef]
56. Rahman, S.; Khan, I.A.; Khan, A.A.; Mallik, A.; Nadeem, M.F. Comprehensive review & impact analysis of integrating projected electric vehicle charging load to the existing low voltage distribution system. *Renew. Sustain. Energy Rev.* **2022**, *153*, 111756. [CrossRef]
57. Yong, J.Y.; Ramachandaramurthy, V.K.; Tan, K.M.; Mithulananthan, N. A review on the state-of-the-art technologies of electric vehicle, its impacts and prospects. *Renew. Sustain. Energy Rev.* **2015**, *49*, 365–385. [CrossRef]
58. Khare, V.; Nema, S.; Baredar, P. Solar–wind hybrid renewable energy system: A review. *Renew. Sustain. Energy Rev.* **2016**, *58*, 23–33. [CrossRef]
59. Mohammed, Y.S.; Mustafa, M.W.; Bashir, N. Hybrid renewable energy systems for off-grid electric power: Review of substantial issues. *Renew. Sustain. Energy Rev.* **2014**, *35*, 527–539. [CrossRef]
60. Muyiwa, A. Wind Resources and Future Energy Security: Environmental, Social, and Economic Issues. 2015. Available online: https://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=996965&site=eds-live (accessed on 1 January 2015).
61. Safipour, R.; Sadegh, M.O. Optimal Planning of Energy storage Systems in Microgrids for Improvement of operation Indices. *Int. J. Renew. Energy Res.* **2018**, *8*, 1483–1498.
62. Ehsan, A.; Yang, Q. Optimal integration and planning of renewable distributed generation in the power distribution networks: A review of analytical techniques. *Appl. Energy* **2018**, *210*, 44–59. [CrossRef]
63. Liu, J.; Chen, X.; Xiang, Y.; Huo, D.; Liu, J. Optimal palanning and investment benefit analysis of shared energy storage of retailers. *Int. J. Electr. Power Energy Syst.* **2020**, *126*, 106561. [CrossRef]
64. Lin, P.; Peng, Z.; Lai, Y.; Cheng, S.; Chen, Z.; Wu, L. Short-term power prediction for photovoltaic power plants using improved Kmeans-GRA-Elman model based on multivariate meteorological factors and historical power datasets. *Energy Convers. Manag.* **2018**, *177*, 704–717. [CrossRef]
65. Eseye, A.T.; Zhang, J.; Zheng, D. Short-term photovoltaic solar power forecasting using a hybrid Wavelet-PSO-SVM model based on SCADA and meteorological information. *Renew. Energy* **2017**, *118*, 357–367. [CrossRef]
66. Ahmad, M.W.; Mourshed, M.; Rezgui, Y. Tree-based ensemble methods for predicting PV poer generation and their comparison with support vector regression. *Energy* **2018**, *164*, 465–474. [CrossRef]
67. Khan, W.; Walker, S.; Zeiler, W. Improved solar photovoltaic energy generation forecast using deep learnin-based ensemble stacking approach. *Energy* **2022**, *240*, 122812. [CrossRef]
68. Patel, A.; Swathika, O.V.G.; Subramanian, U.; Babu, T.S.; Tripathi, A.; Nag, S.; Karthick, A.; Muhibbullah, M. A practical approach for predicting predicting power in a small-scale off-grid photovoltaic system using machine learning algorithms. *Int. J. Photoenergy* **2022**, *2022*, 9194537. [CrossRef]
69. Adibah, Z.; Kamaruzzaman; Mohamed, A. Dynamic Voltage Stability of a Distribution System with High Penetration of Grid-Connected Photovoltaic Type Solar Generator. *J. Electr. Syst.* **2016**, *12*, 239–248.
70. AlShammari, M.M. Evolution of Issues on Distributed Systems: A Systematic Review. In Proceedings of the 2020 19th International Symposium on Distributed Computing and Applications for Business Engineering and Science (DCABES), Xuzhou, China, 16–19 October 2020; pp. 33–37.
71. Das, C.K.; Bass, O.; Kothapalli, G.; Mahmoud, T.S.; Habibi, D. Overview of energy storage systems in distribution networks: Placement, sizing, operation, and power quality. *Renew. Sustain. Energy Rev.* **2018**, *91*, 1205–1230. [CrossRef]
72. Liu, W.; Niu, S.; Xu, H. Optimal planning of battery energy storage considering reliability benefit and operation strategy in active distribution system. *J. Mod. Power Syst. Clean Energy* **2016**, *5*, 177–186. [CrossRef]
73. Phuangpornpitak, N.; Tia, S. Opportunities and Challenges of Integrating Renewable Energy in Smart Grid System. In *10th Eco-Energy and Materials Science and Engineering Symposium*; Elsevier: Amsterdam, The Netherlands, 2013; pp. 282–290.
74. Strezosky, L.; Sajadi, A.; Prica, M.; Loparo, K.A. Distribution System Operational Challenges Following integration of Renewable Generation. In Proceedings of the IEEE Energy Tech, Cleveland, OH, USA, 5 September 2016.

75. Almas, H.; Shahrouz, A.; Jörn, A. The Development of Renewable Energy Sources and Its Significance for the Environment. 2015. Available online: https://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=980370&site=eds-live (accessed on 1 January 2015).
76. Esmaili, M. Placement of minimum distributed generation units observing power losses and voltage stability with network constraints. *IET Gener. Transm. Distrib.* **2013**, *7*, 813–821. [CrossRef]
77. Anderson, P.M.; Fouad, A.A. *Power System Control and Stability*, 2nd ed.; IEEE Press, Inc.: Piscataway, NJ, USA, 2003.
78. Xu, X.; Yan, Z.; Shahidehpour, M.; Wang, H.; Chen, S. Power System Voltage Stability Evaluation Considering Renewable Energy with Correlated Variability. *IEEE Trans. Power Syst.* **2018**, *33*, 3236–3245. [CrossRef]
79. Ayub, M.A.; Khan, H.; Peng, J.; Liu, Y. Consumer-Driven Demand-Side Management Using K-Mean Clustering and Integer Programming in Standalone Renewable Grid. *Energies* **2022**, *15*, 1006. [CrossRef]
80. Sharma, S.; Niazi, K.R.; Verma, K.; Rawat, T. Coordination of different DGs, BESS and demand response for multi-objective optimization of distribution network with special reference to Indian power sector. *Int. J. Electr. Power Energy Syst.* **2020**, *121*, 106074. [CrossRef]
81. Liang, Y.; Deng, T.; Max Shen, Z.-J. Demand-side energy management under time-varying prices. *IISE Trans.* **2019**, *51*, 422–436. [CrossRef]
82. Dey, B.; Basak, S.; Pal, A. Demand-side management based optimal scheduling of distributed generators for clean and economic operation of a microgrid system. *Int. J. Energy Res.* **2022**, *46*, 8817–8837. [CrossRef]
83. Qin, H.; Wu, Z.; Wang, M. Demand-side management for smart grid networks using stochastic linear programming game. *Neural Comput. Appl.* **2020**, *32*, 139–149. [CrossRef]
84. Latifi, M.; Khalili, A.; Rastegarnia, A.; Bazzi, W.M.; Sanel, S. Demand-side management for smart grid via diffusion adaptation. *IThe Inst. Eng. Technol. Smart Grid* **2020**, *3*, 69–82. [CrossRef]
85. Hecht, C.; Sprake, D.; Vagapov, Y.; Anuchin, A. Domestic demand-side management: Analysis of microgrid with renewable energy sources using historical load data. *Electr. Eng.* **2021**, *103*, 1791–1806. [CrossRef]
86. Hossain, A.M.; Chakrabortty, R.K.; Ryan, M.J.; Pota, H.R. Energy Management of Community Energy Storage in Grid-connected Microgrid under Real-time Prices. *Sustain. Cities Soc.* **2020**, *66*, 102658. [CrossRef]
87. Hossain, A.M.; Pota, H.R.; Squartini, S.; Zaman, F.; Guerrero, J.M. Energy Scheduling of Community Microgrid with Battery Cost using Particle Swarm Optimisation. *Appl. Energy* **2019**, *254*, 113723. [CrossRef]
88. Gallo, A.B.; Simões-Moreira, J.R.; Costa, H.K.M.; Santos, M.M.; Moutinho dos Santos, E. Energy storage in the energy transition context: A technology review. *Renew. Sustain. Energy Rev.* **2016**, *65*, 800–822. [CrossRef]
89. Boampong, R. Evaluating the Energy-Saving Effects of a Utility Demand-Side Management Program: A Difference-in-Difference Coarsened Exact Matching Approach. *Energy J.* **2020**, *41*, 185–207. [CrossRef]
90. Rawat, T.; Niazi, K.R.; Gupta, N.; Sharma, S. Impact analysis of demand response on optimal allocation of wind and solar based distributed generations in distribution system. *Energy Sources Part B Econ. Plan. Policy* **2021**, *16*, 75–90. [CrossRef]
91. Mulleriyawage, U.G.K.; Shen, W.X. Impact of demand side management on optimal sizing of residential battery energy storage system. *Renew. Energy Int. J.* **2021**, *172*, 1250–1266. [CrossRef]
92. Rawat, T.; Niazi, K.R.; Gupta, N.; Sharma, S. Joint Allocation and Operational management of DG and BESS in Distribution System in Presence of Demand Response. In Proceedings of the 2019 8th International Conference on Power Systems (ICPS), Jaipur, India, 20–22 December 2019.
93. Ahmad, S.; Alhaisoni, M.; Naeem, M.; Ahmad, A.; Altaf, M. Joint Energy Management and Energy Trading in Residential Microgrid System. *IEEE Access* **2017**, *4*, 123334–123346. [CrossRef]
94. Ochoa, L.F.; Harrison, G.P. Minimizing energy losses: Optimal accommodation and and smart operation of renewable distributed generation. *IEEE Trans. Power Syst.* **2011**, *26*, 198–205. [CrossRef]
95. Hung, D.Q.; Mithulanantan, N. DG allocation in primary distribution systems considering loss reduction. In *Handbook of Renewable Energy Technology*; Zobaa, A.F., Bansal, R.C., Eds.; World Scientific Publishers: Singapore, 2011.
96. Kyritsis, A.; Voglitsis, D.; Papanikolaou, N.; Tselepis, S.; Christodoulou, C.; Gonos, I.; Kalogirou, S.A. Evolution of PV systems in Greece and review of applicable solutions for higher penetration levels. *Renew. Energy Int. J.* **2017**, *109*, 487–499. [CrossRef]
97. Kapoor, K.; Pandey, K.K.; Jain, A.K.; Nandan, A. Evolution of solar energy in India: A review. *Renew. Sustain. Energy Rev.* **2014**, *40*, 475–487. [CrossRef]
98. Castillo-Calzadilla, T.; Cuesta, M.A.; Olivares-Rodriguez, C.; Macarulla, A.M.; Legarda, J.; Borges, C.E. Is it feasible a massive deployment of low voltage direct current microgrids renewable-based? A technical and social sight. *Renew. Sustain. Energy Rev.* **2022**, *161*, 112198. [CrossRef]
99. Centre/BNEF, F.S.-U. Global Trends in Renewable Energy Investment. Available online: http://www.fs-unep-centre.org (accessed on 24 June 2019).
100. Rawat, T.; Niazi, K.R.; Gupta, N.; Sharma, S. A two-stage optimization framework for scheduling of responsive loads in smart distribution system. *Int. J. Electr. Power Energy Syst.* **2021**, *129*, 106859. [CrossRef]
101. Sharma, S.; Niazi, K.R.; Verma, K.; Meena, N.K. Multiple DRPs to maximise the techno-economic benefits of the distribution network. *J. Eng.* **2019**, *2019*, 5240–5244. [CrossRef]
102. Sharma, S.; Niazi, K.R.; Verma, K.; Rawat, T. A bi-level optimization framework for investment planning of distributed generation resources in coordination with demand response. *Energy Sources Part A Recovery Util. Environ. Eff.* **2020**, *42*, 1–18. [CrossRef]

103. Sharma, S.; Niazi, K.R.; Verma, K.; Thokar, R.A. Bilevel optimization framework for impact analysis of DR on optimal accommodation of PV and BESS in distribution system. *Int. J. Electr. Energy Syst.* **2019**, *29*, e12062. [CrossRef]
104. Rawat, T.; Niazi, K.R.; Gupta, N.; Sharma, S. Impact assessment of electric vehicle charging/discharging strategies on the operation management of grid accessible and remote microgrids. *Int. J. Energy Res.* **2019**, *43*, 9034–9048. [CrossRef]
105. Gamage, G.; Withana, N.; Silva, C.; Samarasinghe, R. Battery Energy Storage based Approach for Grid Voltage Regulation in Renewable Rich Distribution Network. In Proceedings of the 2020 2nd IEEE International Conference on Industrial Electronics for Sustainable Energy Systems (IESES), Cagliari, Italy, 1–3 September 2020.
106. Chauhan, A.; Saini, R.P. A review on Integrated Renewable Energy System based power generation for stand-alone applications: Configurations, storage options, sizing methodologies and control. *Renew. Sustain. Energy Rev.* **2014**, *38*, 99–120. [CrossRef]
107. Georgilakis, P.S.; Hatziargyriou, N.D. Optimal Distributed Generation Placement in Power Distribution Networks: Models, Methods and future Research. *IEEE Trans. Power Syst.* **2013**, *28*, 3420–3428. [CrossRef]
108. Riaz, M.; Ahmad, S.; Hussain, I.; Mihet-Popa, L. Probabilistic Optimization Techniques in Smart Power System. *Energies* **2022**, *15*, 825. [CrossRef]
109. Rawat, T.; Niazi, K.R.; Gupta, N.; Sharma, S. A linearized multi-objective Bi-level approach for operation of smart distribution systems encompassing demand response. *Energy* **2022**, *238*, 121991. [CrossRef]
110. Sharma, S.; Niazi, K.R.; Verma, K.; Rawat, T. Impact of Multiple Battery Energy Storage System Strategies on Energy Loss of Active Distribution Network. *Int. J. Renew. Energy Res.* **2019**, *9*, 1705–1711.
111. Tan, W.-S.; Hassan, M.Y.; Majid, M.S.; Abdul Rahman, H. Optimal distributed renewable generation planning: A review of different approaches. *Renew. Sustain. Energy Rev.* **2013**, *18*, 626–645. [CrossRef]
112. Thokar, R.A.; Gupta, N.; Swarnkar, A.; Sharma, S.; Meena, N.K. Optimal Integration and Management of Solar Generation and Battery Storage System in Distribution Systems under Uncertain Environment. *Int. J. Renew. Energy Res.* **2020**, *10*, 11–12.
113. Sandhu, K.S.; Mahesh, A. Optimal sizing of PV/wind/battery Hybrid Renewable Energy System Considering Demand Side Management. *Int. J. Electr. Eng. Inform.* **2018**, *10*, 79–93. [CrossRef]
114. Arias, L.A.; Rivas, E.; Santamaria, F.; Hernandez, V. A Review and Analysis of Trends Related to Demand Response. *Energies* **2018**, *11*, 1617. [CrossRef]
115. Hakimi, S.M.; Moghaddas-Tafreshi, S.M. Optimal Planning of a Smart Microgrid Including Demand Response and Intermittent Renewable Energy Resources. *IEEE Trans. Smart Grid* **2014**, *5*, 2889–2900. [CrossRef]
116. Setlhaolo, D.; Xia, X.; Zhang, J. Optimal scheduling of household apppliances for demand response. *Electr. Power Syst. Res.* **2014**, *116*, 24–28. [CrossRef]
117. Hussain, I.; Mohsin, S.; Basit, A.; Khan, Z.A.; Qasim, U.; Javai, N. A review on Demand Response: Pricing, Optimization, and Appliance Scheduling. In *6th International Conference on Ambient Systems, Network and Technologies, ANT 2015*; Elsevier: Amsterdam, The Netherlands, 2015.
118. Sharma, S.; Niazi, K.R.; Verma, K.; Rawat, T. Impact of battery energy storage, controllable load and network reconfiguration on contemporary distribution network under uncertain environment. *IET Gener. Transm. Distrib.* **2020**, *14*, 4719–4727. [CrossRef]
119. Ding, M.; Xu, Z.; Wang, W.; Wang, X.; Song, Y.; Chen, D. A review on China's large-scale PV integration: Progress, challenges and recommendations. *Renew. Sustain. Energy Rev.* **2016**, *53*, 630–652. [CrossRef]
120. Parizy, E.S.; Ardakani, A.J.; Mahammadi, A.; Loparo, K.A. A new quantitative load profile measure for demand response performance evaluation. *Electr. Power Energy Syst.* **2020**, *121*, 106073. [CrossRef]