



REVIEW ARTICLE

RECENT TRENDS IN THE OPTIMAL RENEWABLE POWER DISPATCH FRAMEWORKS IN RENEWABLE ENERGY-RELIANT POWER SYSTEMS

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ABSTRACT

This study presents a comprehensive survey of Optimal Renewable Power Dispatch (ORPD) frameworks in grid-rich renewables. The work employs comparative, and trend approaches to analyze optimization methods for ORPD of 61 relevant studies published from 2018 to 2024 by making use seven parameters emerged from the overall studies include voltage stability, carbon footprint, active power, reactive power, power loss, congestion, and energy storage. The results were tabulated using bibliometric tables, trend analysis, charts, and figures. The results show that previous research mainly emphasized minimizing economic cost through active power and loss optimization. However, voltage stability and congestion constraints were rarely integrated into the optimization framework simultaneously. Despite this, most studies remain focused on tackling these issues individually, where voltage stability is usually treated as a minor constraint, loss minimization is framed as a separate objective, and congestion management is approached through standalone mechanisms. While some integrated frameworks exist, they often address a limited scope of objectives, resulting in omissions in the development of comprehensive models. To close this significant research gap, there is need for the development of robust, multi-objective, and computationally efficient frameworks that holistically address these intertwined issues. The findings will therefore have academic, technical, and practical relevance, offering both theoretical contributions and actionable solutions for future power system planning and operation.

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1.0 Introduction

Traditionally, electricity generated through conventional sources have long proven as most stable but they contributed significantly to global warming as a result of pronounced carbon dioxide (CO<sub>2</sub>) footprint and capially expensive in terms of maintenance (Das et al., 2021; Das and De, 2023; Mayer et al., 2020). However, many research effort have been devoted to mitigation of climate change for planet protection (Fawzy et al., 2020; Kaack et al., 2022; Lehmann et al., 2021; Olabi and Abdelkareem, 2022). Subsequently, with the emphasis on mitigating climatic factors, the addition of green energy plants and energy storage (ES) facilities are also important (Monforti-Ferrario and Blanco, 2021; and Sifakis et al., 2021). A search through literatures show wide sparsity of understanding on the related inclusion of renewable energy sources (RESs) and storage units in system stability models (Ahmed et al., 2022; Fatin Ishraque et al., 2021; Miracle et al., 2023; and Numan et al., 2023).

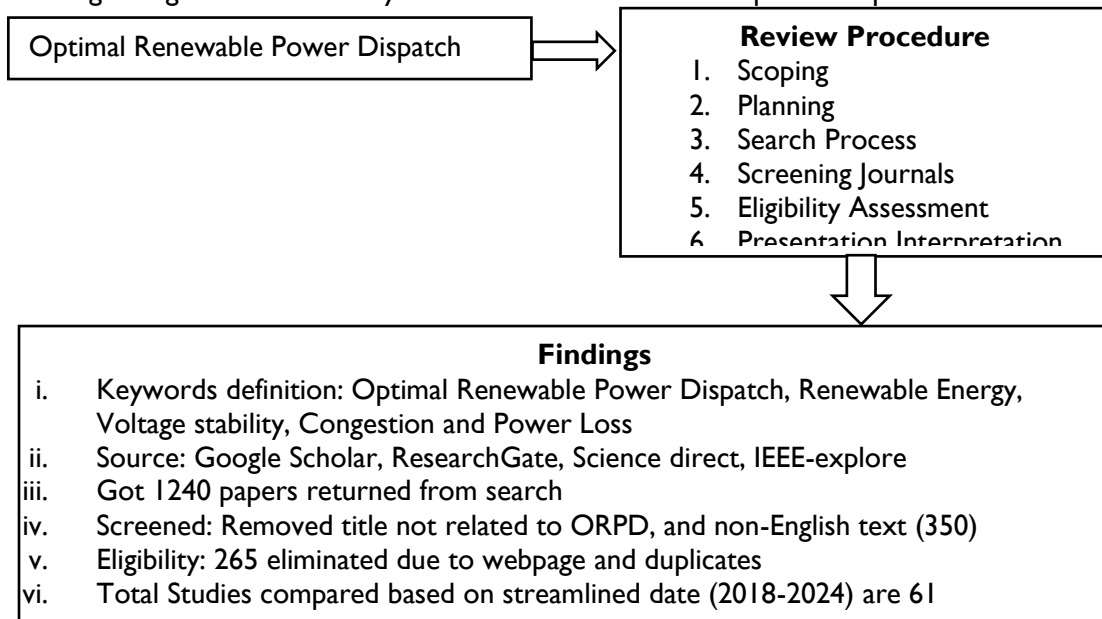
1.1 Background and Context

The global migration to sustainable energy has increased the penetration of RESs within electrical distribution systems. While this transformation supports sustainable goals, it as well mitigates dependence on conventional fossil-based energy (Husin et al., 2021; Infield and Freris, 2020; Shafiu Alam et al., 2020; and Sinsel et al., 2020).

This transition brings operational challenges because of the intermittent and non-linear structure of RESs (Bajaj and Singh, 2020; Mararakanye and Bekker, 2019; and Worighi *et al.*, 2019). Power losses (PL), non-optimal generation dispatch, voltage instability and congestion are part of the most common pressing issues. The RESs variability and reliance on inverter-based interfaces result to limited reactive power (Q) support and inertial, making systems more prone to voltage instability, especially in weakly interconnected areas. Renewables are often sited far from load centers, requiring long-distance transmission that increases the line losses, while intermittent injections and reverse flows in distribution networks further increase technical losses. In addition, the spatial mismatch between renewable generation hubs and demand centers frequently overloads transmission environments, creating congestion that is harder to manage with reduced availability of flexible classical generation. Although, several studies such as those by Hosseinzadeh *et al.* (2021), Sifakis *et al.* (2021), and Yan *et al.* (2024) have addressed individual objectives like eco-economic optimization and loss minimization, none provide a holistic ORPD framework that rigorously integrates voltage stability constraints together with loss and congestion management. Therefore, there is need to address this gap to mitigate congestion and power losses simultaneously.

## 2. Methodology

Figure 1 presents the systematic review process adopted in this study to analyze recent developments in ORPD frameworks between 2018 and 2024. The flowchart illustrates a structured and transparent review pipeline that ensures reproductivity and minimizes selection bias. The methodology combines elements of scoping review, bibliometric mapping, and comparative thematic analysis, providing both breadth and depth in the investigation of ORPD research. Overall, the figure shows a robust and thorough methodology that combines number-crunching both bibliometric with in-depth qualitative content evaluation, ensuring the results accurately reflect preferred method, current trends and emerging needs within ORPD research. This methodological rigor forms the analytical foundation for the subsequent comparative assessment in Table 1.



**Figure 1:** Methodological Technique for the reviewed studies

### 2.1 Search Strategy

It is evident in Figure 1 that the procedure starts with scoping and planning that involves defining the review boundaries, identifying research gaps, and formulating key search terms around core ORPD parameters, which are, Voltage Stability (VS), Congestion Management (CG) and Power Loss reduction (PL). The search process leveraged multiple reputable databases that include ResearchGate, IEEE Xplore, Google Scholar, and Science Direct, which ensure broad coverage of peer-reviewed publications.

### 2.2 Inclusion/Exclusion Criteria

A total of 1,240 studies were initially retrieved, after which titles and abstracts were screened to exclude non-English papers, duplicates, and those unrelated to ORPD, leaving 350 papers. Further eligibility assessment

filtered out 265 additional papers that lacked relevance datasets, culminating in a final dataset of 61 studies meeting all inclusion criteria. This rigorous filtration underscores the methodological reliability of the study.

### 2.3 Data Extraction and Classification

Figure 1 also captures the data extraction and classification stage, where selected papers were categorized by optimization objective (single or multi-objective), methodological approach (mathematical, metaheuristic, hybrid), and addressed parameters VS, Carbon Footprint (CO<sub>2</sub>), Active Power (P), Reactive Power (Q), PL, CG, and Energy Storage (ES). The final presentation and interpretation stage involved thematic synthesis, statistical analysis, and visualization through figures, tables and trend charts.

## 3. ORPD Publications Analysis

### 3.1 Overview of Reviewed Studies

Earlier studies have explored various optimization techniques for RESs dispatch, among which are Genetic Algorithm (Mayer, *et al.*, 2020; and Marouani, *et al.*, 2022), Particle Swarm Optimization (Barakat *et al.*, 2020; and Sharma *et al.*, 2023) and hybrid metaheuristics (Waleed *et al.*, 2022). However, only a limited number explicitly incorporate voltage stability constraints without inclusion of PL and CG objectives (Hosseinzadeh *et al.*, 2021). For example, Ghada *et al.* (2024) applied Jellyfish Search Algorithm (JSA) to enhance voltage stability using Static Var Compensators. Similarly, Karthik *et al.* (2021) proposed Levy Interior Search Algorithm (LISA) for reactive power management, showing enhancement of system voltage levels and decreased system losses but neglect congestion framework. African Vulture Optimization Algorithm (AVOA) has also demonstrated effectiveness in large-scale dispatch scenarios in another work (Ali *et al.*, 2023). Numerous studies have also worked on purely economic dispatch of renewable-rich grid systems (Ahmed *et al.* 2022; Chen *et al.*, 2023; and Yang *et al.*, 2023) and their results showed high performances but neglect of voltage stability indices as a constraint still remain the bottleneck. In other studies, techno-economic dominated their works (Ebeed *et al.*, 2020; Garrido-Arévalo *et al.*, 2024; Sharma *et al.*, 2023; and Xiong *et al.*, 2022) and the methods strength lie in its effectiveness of handling power dispatch issues. Subsequently, some studies delved into planning assessment (Elkadeem *et al.*, 2020; Montoya, 2023; and Shafiu Alam *et al.*, 2020). Furthermore, only a few dogged-on voltage constraints during optimal dispatch (Hosseinzadeh *et al.*, 2021; Abhishek *et al.*, 2023; and Hassan *et al.*, 2020). However, majority of the methods still solved a subset of the problem while the holistic framework is missing. Despite these advances, most studies focus on economic dispatch or emission reduction, often neglecting voltage stability and congestion mitigation (Sifakis *et al.*, 2021; and Purlu and Turkay, 2022).

#### 3.1.1 Voltage stability in electrical energy systems

Voltage robustness is crucial in sustaining the power systems' integrity over centuries especially under high-RES integration. Meanwhile, voltage collapse can result from load demand, imbalance reactive power support and the intermittent nature of RESs (Malbasa *et al.*, 2017; and Pinzón and Colomé, 2019). Also, in the earlier stage, traditional methods such as PV and QV curve analysis enhanced knowledge into static stability margins (Ajarapu and Christy, 2002), while progressive approaches later provided more authentic assessment of system response to disturbances (Zhang *et al.*, 2015). Subsequently, convectional dispatch models commonly focus on emission or economic objectives, neglecting voltage constraints (Chi and Xu, 2020; and Lin *et al.*, 2022). With present-day grids undergoing progressive complexity, priority has been given to embedded voltage stability indices into optimization techniques. For example, a work proposes an optimal power flow formulation incorporating voltage stability constraints to mitigate the variability of distributed renewable generation (Hosseinzadeh *et al.*, 2021) and another study improved on this method with rigorous formulations that explicitly incorporate renewable uncertainties (Sharma *et al.*, 2023). Regardless of these advances, most studies only focused on stability constraints alone, without combining them to objectives such as congestion mitigation and power loss reduction.

#### 3.1.2 Congestion mitigation in power networks

Congestion occurs as a result of unbalance between power supply and power demand due to transmission line exceeding its thermal limit leading to increased losses and reduced reliability (Monforti-Ferrario and Blanco, 2021; Paul *et al.*, 2021; and Tomar, 2024). System congestion has been extensively studied due to its operational and economic significance, especially in deregulation markets. Initial investigations focused on market-based mechanisms namely congestion pricing and locational marginal pricing (Bai *et al.*, 2017), whereas non-market approaches have relied on demand side management, FACTS development and re-dispatch

(Narain *et al.*, 2020; and Yousefi *et al.*, 2012). Considering the rising penetration of RE, congestion management has exhibited greater complexity arising from variability in transmission and generation limitations (Dashtdar *et al.*, 2020; Paul *et al.*, 2021; Sarwar *et al.*, 2022; Tomar, 2024; and Wang *et al.*, 2018). Even though these techniques deliver effective short-term alleviation, most techniques handle congestion in isolation without explicitly integrating power loss reduction or voltage stability as co-objectives.

### **3.1.3 Optimal power dispatch**

An effective power dispatch network is important for sustaining network reliability and enhancing steady system operation, optimizing load demand and reduction of line losses. The economic dispatch issue has classically concentrated on generation costs as well as meeting demand under deterministic conditions (Aziz *et al.*, 2021; Candra *et al.*, 2024; Liu *et al.*, 2021; and Xu *et al.*, 2021). Yet, the stochastic nature of renewable sources query these conventional techniques, propelling research toward robust and stochastic optimization methods (Chi and Xu, 2020; Huang *et al.*, 2019; Lin *et al.*, 2022; Roustaei *et al.*, 2022; and Wang *et al.*, 2020). Recently, hybrid RE to innovative grid-based networks, embedding energy storage mechanisms with demand response have been presented to optimize dispatch flexibility (Liu and Li, 2016), and more current formulations extensively cater for renewable uncertainties during continuous operations (Ding *et al.*, 2020; and Zhang *et al.*, 2020). Despite these formulations enhancing reliability, majority still focus on cost minimization as the primary objective with little attention to congestion or voltage stability constraints.

### **3.1.4 Power loss reduction methods**

Improving efficiency through loss minimization in transmission and distribution networks persists as vital operational priority, particularly since the incorporation of RE changes conventional system flow configurations. Traditional methods entail grid restructuring and reactive power compensation (Nkan *et al.*, 2021), though FACTS devices have been evidenced to substantially strengthen system flexibility and decrease power losses (do Carmo Mendonça *et al.*, 2020; Ghada *et al.*, 2024; Rao *et al.*, 2024; Reddy, 2021; and Zubidi *et al.*, 2023). Metaheuristic-based optimization methods encompassing GA, PSO as well as Evolutionary Algorithms (EO) have been excellent approaches for optimizing power loss mitigation techniques in distribution networks (Aljebreen *et al.*, 2023; Karthik *et al.*, 2021; Othman *et al.*, 2025; Sadiq and Antar, 2024; Sambaiah and Jayabarathi, 2020; and Ushashree and Kumar, 2023). Current research trends expand these techniques to renewable-intensive settings, under conditions where uncertainty hinders operational efficiency enhancement (Ali *et al.*, 2023; Eladl and ElDesouky, 2019; Elkadeem *et al.*, 2019; Hmingthanmawia *et al.*, 2023; Khan *et al.*, 2020; and Waleed *et al.*, 2022). Conversely, reducing losses is frequently handled as an independent optimization objective without deliberate alignment with congestion management or stability constraints.

### **3.1.5 Integrated approaches**

Addressing the interactions among power system objectives, studies have proposed comprehensive frameworks that account for combination of congestion, stability and losses. Multi-criteria optimization strategies such as algorithms have been broadly adopted to achieve equilibrium among divergent objectives (Infield and Freris, 2020; Ismael *et al.*, 2019; Mohandes *et al.*, 2019; and Sinsel *et al.*, 2020). Some studies have shown high system performance with embedded stability and congestion objectives in OPF frameworks. (Sekhavatmanesh and Cherkaoui, 2018; and Zhao *et al.*, 2022). Alternatively, other studies have merged FACTS placement with multi-objective optimization for grid performance efficiency (Li, 2024). Nevertheless, these researches typically examine bi-objective configurations instead of unified models. Therefore, existing study considering voltage stability-constraints, RE dispatch, congestion mitigation and power loss reduction within an inclusive optimization domain remains limited.

## **3.2 Emerging Themes**

Table I provides a detailed comparison of 61 studies on ORPD published between 2018 and 2024. It captures key attributes including optimization orientation, quadratic function usage, addressed parameters, and applied methods. The table serves as the foundation of progress identification, research gaps and thematic synthesis. Therefore, it is explicitly explained using figures 1 to 5.

**Table I:** Comparative analysis of studies on ORPD from 2018-2024

S/N	Author with Date	MO/ SO	QD	Problem Addressed							Method used
				VS	CO <sub>2</sub>	P	Q	PL	CG	ES	
1	Kholi and Arora (2018)	MO	✓	✓	✓	✓	✓	✓	✗	✗	CGWO
2	Biswas et al., (2018)	MO	✓	✓	✓	✓	✓	✓	✗	✗	DEA
3	Biswas et al., (2018)	both	✓	✗	✗	✓	✓	✓	✗	✗	SHADE
4	Suresh et al., (2019)	MO	✓	✓	✓	✓	✗	✓	✗	✗	ADFA
5	Elattar et al., (2019)	SO	✓	✓	✓	✓	✓	✓	✓	✗	MJAYA
6	Eladi et al., (2019)	SO	✓	✗	✗	✓	✗	✗	✗	✗	PSO-SOP
7	Velasquez et al., (2019)	SO	✓	✗	✗	✓	✗	✗	✗	✗	DMPC
8	Chen et al., (2019)	MO	✓	✓	✓	✓	✓	✗	✓	✗	CMOPEO+SF
9	Naval et al., (2019)	SO	✗	✗	✗	✓	✗	✗	✗	✗	MILP
10	Alomoush, (2019)	both	✓	✗	✓	✓	✗	✓	✗	✗	SFS
11	Elkadeem et al., (2019)	MO	✓	✓	✗	✓	✗	✓	✓	✗	HHO-PSO
12	Wang et al., (2019)	SO	✗	✗	✗	✗	✓	✓	✗	✗	PSO
13	Vaziri et al., (2019)	MO	✗	✗	✗	✗	✗	✗	✗	✗	MILP
14	Zhou et al., (2019)	SO	✓	✓	✗	✓	✗	✗	✗	✓	ATC
15	Hooshmand et al., (2019)	MO	✓	✓	✗	✓	✓	✓	✗	✓	MISOCP
16	Wang et al., (2020)	SO	✗	✗	✗	✓	✗	✗	✗	✓	IBESSD
17	Hassan et al., (2020)	MO	✓	✓	✓	✓	✓	✓	✓	✓	MNLP
18	Inam et al., (2020)	SO	✓	✓	✓	✓	✓	✓	✗	✗	GWO
19	Nusair et al., (2020)	both	✓	✓	✓	✓	✓	✓	✗	✗	GROM
20	Ebeed et al., (2020)	MO	✓	✓	✗	✓	✓	✓	✗	✗	MPA
21	Murty and Kumar, (2020)	MO	✓	✗	✓	✓	✗	✗	✗	✓	HOMER
22	Abazal et al., (2020)	both	✓	✓	✗	✓	✓	✓	✗	✗	ECOEA
23	Ebeed et al., (2020)	MO	✓	✓	✗	✓	✓	✓	✗	✗	ILAPO
24	Yousif et al., (2020)	MO	✓	✗	✓	✓	✗	✓	✗	✓	PSO
25	Chamandous et al., (2020)	MO	✓	✗	✓	✓	✗	✗	✗	✓	GAMS/DICOPT
26	Elattar and Elsayed (2020)	SO	✓	✓	✓	✓	✓	✓	✓	✗	MMFO
27	Ettappan et al., (2020)	MO	✓	✓	✗	✓	✓	✓	✗	✗	ABC
28	Gbadamosi and Nwulu (2020)	MO	✓	✗	✓	✓	✗	✓	✗	✗	MIQP
29	Xu et al., (2020)	MO	✗	✗	✓	✓	✗	✗	✗	✓	PSO
30	Vishnu et al., (2020)	MO	✓	✓	✗	✓	✓	✓	✗	✗	DEPSO
31	Azralmukmin et al., (2020)	SO	✓	✗	✗	✓	✗	✓	✗	✗	COR
32	Hodge et al., (2020)	MO	✓	✓	✗	✓	✗	✓	✗	✗	Systematic
33	Ismail et al., (2020)	MO	NS	✓	✗	✓	✓	✓	✓	✓	Systematic
34	Nikkhah et al., (2020)	SO	✓	✓	✗	✓	✓	✓	✗	✓	MINLP
35	Nasr et al., (2020)	MO	✓	✓	✗	✓	✓	✓	✗	✓	MINLP
36	Ishraque et al., (2021)	MO	✓	✓	✓	✓	✗	✓	✗	✓	HOMER
37	Liu et al., (2021)	MO	✓	✗	✗	✓	✗	✗	✗	✓	NSGAI+TOPSIS
38	Sakthivel et al., (2021)	MO	✓	✗	✓	✓	✗	✓	✓	✗	MOSSA
39	Ogunmodede et al., (2021)	SO	✗	✗	✗	✓	✗	✗	✗	✓	MILP
40	Liu et al., (2021)	MO	✗	✓	✓	✓	✗	✓	✗	✓	IOD
41	Bravo et al., (2021)	MO	✓	✗	✓	✓	✗	✗	✗	✓	MOO
42	Ordoudis et al., (2021)	MO	✓	✗	✓	✓	✗	✗	✓	✓	DCC
43	Guo et al., (2021)	MO	✗	✗	✓	✗	✗	✗	✗	✓	Bi-Level
44	Sifakis et al., (2021)	MO	✓	✗	✓	✓	✗	✗	✗	✓	HOMER
45	Liu et al., (2021)	MO	✓	✗	✓	✓	✗	✓	✗	✗	MFO-PDU
46	Hassan et al., (2021)	both	✓	✓	✗	✓	✓	✓	✗	✓	Systematic
47	Xie et al., (2021)	SO	✗	✓	✗	✓	✓	✓	✓	✗	Not specified



**Table I contd.:** Comparative analysis of studies on ORPD from 2018-2024

S/N	Author with Date	MO/ SO	QD	Problem Addressed							Method used
				VS	CO <sub>2</sub>	P	Q	PL	CG	ES	
48	Mohandes et al., (2021)	MO	☒	☒	☒	☑	☒	☒	☒	☑	GA
49	Saddique et al., (2022)	SO	☑	☑	☒	☒	☑	☑	☒	☒	CA
50	Vergara et al., (2022)	SO	☑	☑	☒	☑	☑	☑	☒	☒	RL
51	Liu et al., (2022)	MO	☑	☑	☒	☒	☑	☑	☒	☒	IGA
52	Purlu et al., (2022)	both	☑	☑	☒	☑	☑	☑	☒	☑	GA, PSO
53	Ali et al., (2023)	MO	☑	☑	☒	☑	☑	☑	☒	☑	Monte Carlo
54	Gholami et al., (2023)	both	☑	☒	☑	☑	☒	☑	☒	☒	SACDE
55	Chapaloglou et al., (2023)	MO	☑	☑	☑	☑	☒	☑	☒	☑	Probabilistic
56	Chen et al., (2023)	SO	☒	☒	☒	☑	☒	☑	☒	☒	Two-Stage
57	Miracle et al., (2023)	MO	☑	☒	☒	☑	☒	☑	☒	☒	POCSO
58	Barnawi et al., (2024)	MO	NS	☑	☑	☑	☑	☑	☒	☑	GNDO
59	Li et al., (2024)	MO	☑	☑	☒	☑	☑	☑	☒	☒	PSO
60	Mohammed et al., (2024)	both	☑	☑	☑	☑	☑	☑	☑	☒	CGO
61	Alayande et al., (2024)	MO	☑	☑	☑	☑	☑	☑	☒	☑	BBS

**ABC:** Artificial Bee Colony; **ADFA:** Ameliorated Dragonfly Algorithm; **ATC:** Analytical Target Cascading; **BBS:** Bus bar Synchronization; **CGO:** Chaos Game Optimization; **CGWO:** Constrained Grey Wolf Optimization; **CMOPEO+SF:** Constrained Multi-objective Population Extrema Optimization; **DEA:** Differential Evolution Algorithm; **DEPSO:** Diversity Enhanced PSO; **DMCP:** Distributed Model Predictive Control; **ECOA:** Enhanced Coyote Optimization Algorithm; **GA:** Genetic Algorithm; **GROM:** Golden Ratio Optimization Method; **GWO:** Grey Wolf Optimization; **HHO:** Harris Hawks Optimization; **HOMER:** Hybrid Optimization of Multiple Energy Resources; **IBESSD:** Improved Battery Energy Storage; **IGA:** Improved Genetic Algorithm; **ILAPO:** Improved Lightning Attachment Procedure Optimization; **IOD:** Integrated Optimal Dispatch Strategy; **MFO-PDU:** Enhanced Moth Flame Optimization; **MILP:** Mixed Integral Linear Programming **MINLP:** Mixed Integral Non-Linear Programming; **MIQP:** Mixed Integer Quadratic Programming; **MISOCP:** Mixed Integral with Soft Computing Programming; **MMFO:** Modified Month Flame Optimization; **MO:** Multi-Objective; **MOSA:** Modified Optimization Swarm Algorithm; **MPA:** Marine Predator Algorithm; **NS:** Not specified; **PSO:** Particle Swarm Optimization; **QD:** Quadratic Function; **RL:** Reinforcement Learning; **SACDE:** Self-Adaptive Comprehensive Differential Evolution Algorithm; **SCA:** Sine-Cosine Algorithm; **SFS:** Stochastic Fractal Search; **SHADE:** Success History Based Adaptive Differential Evolution; **SO:** Single Objective; **SQP:** Sequential Quadratic Programming

### 3.2.1 ORPD publications

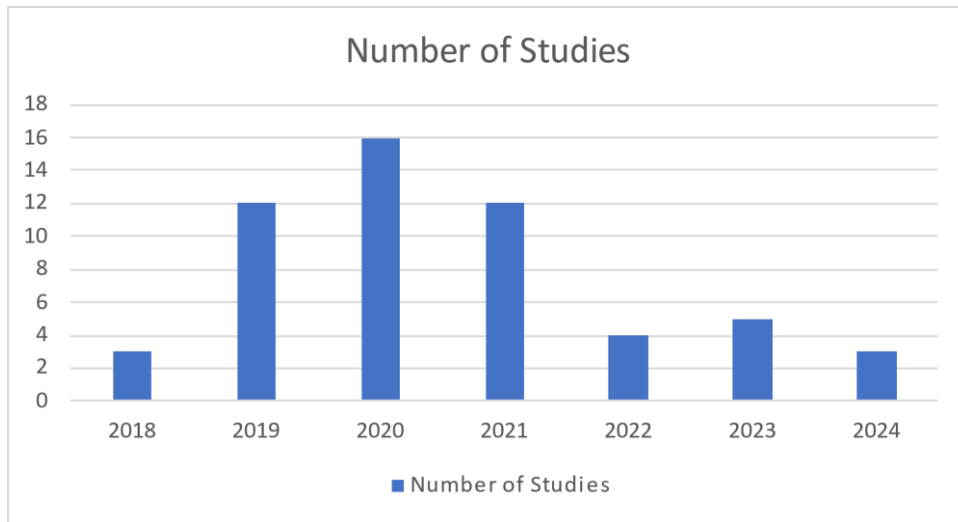
Figure 2 maps the yearly count of reviewed studies on ORPD between 2018 and 2024. The publication history shows research interest in the field has fluctuated but grown overall. The lowest publication numbers were recorded in 2018 and 2024, with three studies each. This suggests the field was either in its early exploratory stages (2018) or potentially reaching a point of saturation or shifting to newer research paradigms (2024). The peak was reached in 2020, with 16 published studies. This surge likely reflects increased global efforts to better integrate renewables, alongside the practical maturity of metaheuristic optimization tools (Das et al., 2021; and Elkadeem et al., 2020). The high output that year could also be tied to advancements in hybrid optimization algorithms and the development of smart grid integration models (Panda & Nayak, 2022; and Liu et al., 2021).

The steady, moderate number of studies between 2019 and 2021 (12 each year) suggests the research consolidated into practical topics like reactive power dispatch, stability analysis, and congestion management (Hosseinzadeh et al., 2021; and Sharma et al., 2023). However, the drop-off after 2022 (down to four or five studies) points to a subtle shift in focus. While the core field has matured, attention is gradually moving toward AI-based, decentralized, and data-driven dispatch models (Chen et al., 2023; and Ali et al., 2023). Summarily, Figure 2 shows that ORPD research reached its height during the peak period of global renewable integration, and the current, evolving interest is centered on developing advanced hybrid and intelligent optimization models for a more resilient and sustainable grid.

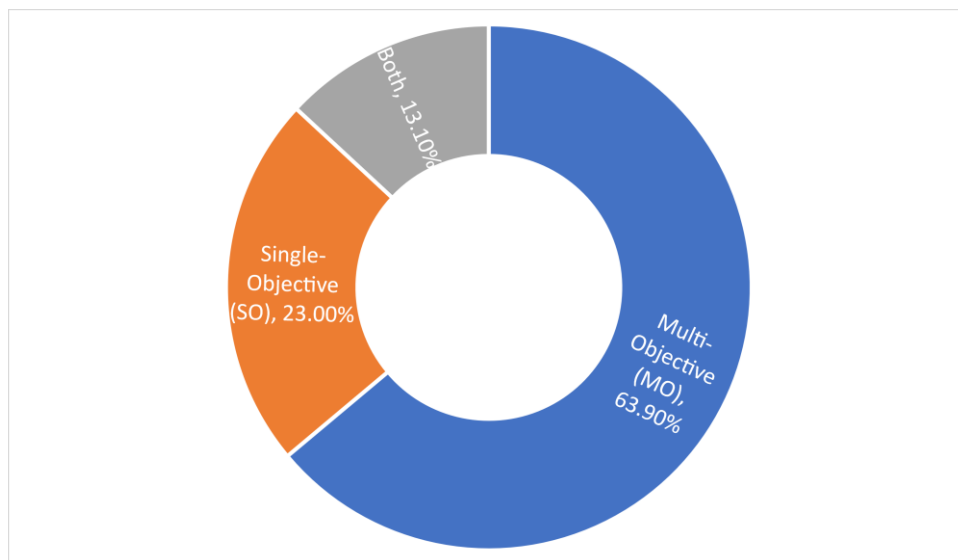
### 3.2.2 Objective function types

A clear pattern emerged from the tabulated data resulted to figure 3 where multi-objective (MO) optimization frameworks overwhelmingly dominate recent research, accounting for more than half of the reviewed works (63.90%). These approaches simultaneously target multiple goals such as emission reduction, power loss mitigation, cost minimization, and voltage stability enhancement. Conversely, single-objective (SO)

formulations constitute 23.00%, though still relevant and once common in early economic dispatch studies, but gradually declining due to their inability to handle multidimensional nature renewable-dominated grids. A small subset of studies (13.10%) employed hybrid structures, reflecting the transition towards adaptive and flexible optimization paradigms.



**Figure 2: ORPD Publication Analysis**



**Figure 3: Objective Function Types**

### 3.2.3 Methodology trends

Regarding optimization algorithms, figure 4 highlights the rapid development of computational intelligence in ORPD. Widely used metaheuristic algorithms (57%) include PSO, GA, GWO, HHO, and ABC, all valued for their ability to manage complex, non-linear dispatch problems. Hybrid and advanced methods like PSO–SQP, HHO–PSO, MPA and ILAPO signal a methodological drive (12%) toward better convergence reliability and more accurate solutions. Recent studies also incorporate AI-based frameworks (5%) such as Reinforcement Learning (RL), Self-Adaptive Comprehensive Differential Evolution (SACDE), and Chaos Game Optimization (CGO), underlining the ongoing digital transformation of power-system optimization.

### 3.2.4 Multi-parameter synergy

Looking at the seven parameters addressed, P and PL optimization dominate the research landscape, featuring in over two-thirds of the reviewed papers. VS shows as a constraint or goal in a fair number of studies, underscoring its rising importance especially with more renewables, it is still underrepresented relative to purely economic objectives. CG and ES are noticeably underexplored, appearing in fewer than 20% of the works. This evidence confirms a major gap in fully integrated dispatch models. Very view studies specifically

those using MILP or Bi-Level techniques explicitly bring CG stability and loss into a single framework. Moreover, Figure 5 highlights the growing inclusion of Battery Energy Storage System (BESS) and Hybrid RE Systems (HRES) in dispatch formulations, confirming a welcome shift towards designing for flexibility and resilience, and better dynamic balancing into grid. The recent (2022-2024) to advanced AI techniques like RL, SACDE, and CGO shows an emerging trend towards AI-driven. Data-adaptive optimization models. Hence, the transition underscores just how complex power system operation has become in grid dominated by renewables.

### Optimization Method

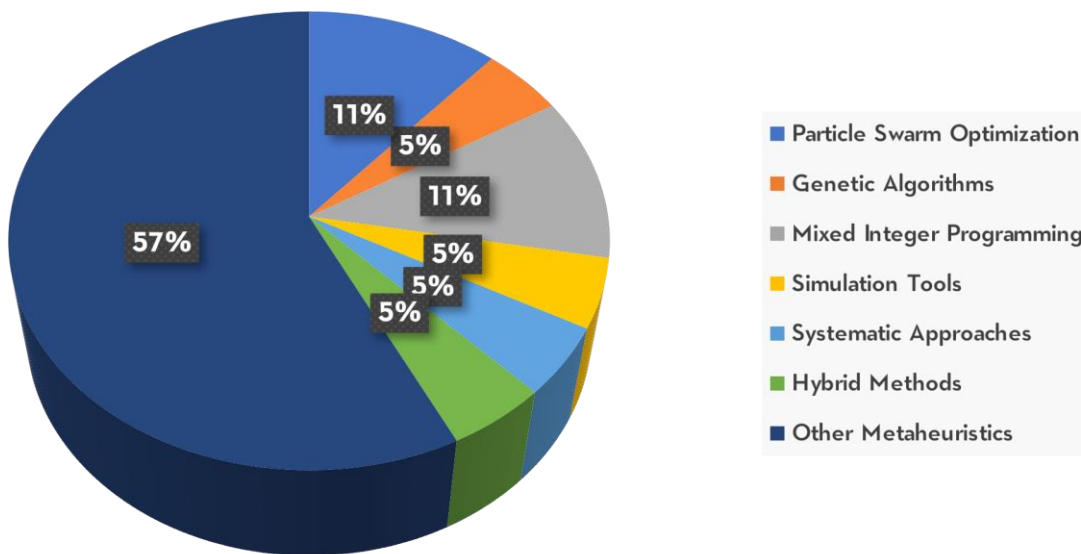


Figure 4: Optimization Methods

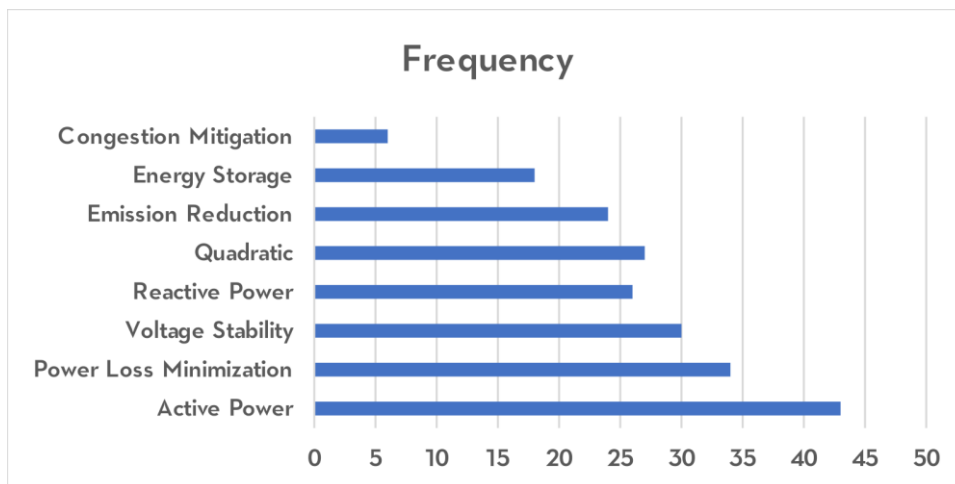


Figure 5: Multi-Parameter Variables

### 3.3 Implications for Future Research and Practice

The analysis of the tables and figures provides several critical implications for the future of ORPD: The dominance of multi-objective optimization highlights that dispatch in renewable-integrated grids is inherently multi-dimensional. This confirms that simple single-objective models, which only focus on minimizing cost or loss, are inadequate because they ignore crucial factors like voltage stability and reliability. The shift in algorithms from classical methods to hybrid and AI-based models signals a move toward intelligent and adaptive dispatch. Methods like RL, Genetic–Swarm hybrids, and Self-Adaptive Differential Evolution manage system non-linearity and uncertainty better and will likely become the standard as grid complexity increases.



The parameter synergy analysis (Figure 5) confirms that while active power and loss minimization are mature fields, parameters like voltage stability, congestion management, and energy-storage integration are underdeveloped. This means current strategies risk operational efficiency without ensuring long-term grid resilience. The priority must be to develop unified frameworks that integrate these critical, underexplored factors. Subsequently, publication trends show that after a period of theoretical development, researchers are now pivoting toward implementation-oriented and application-specific frameworks, particularly in areas like microgrids and peer-to-peer energy markets. Finally, the future of ORPD lies in multi-parameter, AI-driven, and stability-constrained optimization systems that are essential for supporting flexible, sustainable, and autonomous power networks.

#### 4. Conclusion

This review has thoroughly analyzed recent developments in ORPD between 2018 and 2024. The findings confirm that while major strides in optimization modelling, existing frameworks often suffer from fragmentation, treating essential elements like voltage stability, power losses, and congestion as isolated objectives instead of as interconnected operational constraints. The literature reveals a historical bias toward cost-driven dispatch, where economic optimization often overshadows the need for reliability and voltage security. As a result, system operators continue to struggle with maintaining stable voltage profiles, reducing line losses, and managing congestion under high renewable penetration. Though advanced multi-objective and metaheuristic algorithms (like GA, PSO, HHO, and their hybrids) have been successful in balancing cost and loss, they frequently fail to include real-time voltage stability constraints and network congestion parameters. Few integrated models exist that simultaneously tackle all the critical variables: voltage stability, congestion mitigation, and power loss reduction within a single optimization domain. Based on this synthesis, the three top priorities identified for future ORPD research are:

1. Developing unified frameworks that holistically combine voltage stability indices, congestion control, and loss minimization, all while accounting for renewable energy uncertainty.
2. Adopting intelligent, data-driven optimization techniques like machine learning and reinforcement learning to boost the adaptability and decision speed of dispatch systems.
3. Integrating energy storage and smart-grid coordination to enhance system resilience, enable real-time stability control, and optimize distributed renewable generation.

To achieve reliable and sustainable renewable-dominated grids, the industry must transit from traditional, cost-based methods to multi-objective, stability-constrained, and AI-supported ORPD frameworks. These advanced systems will not only improve power quality and voltage security but will also dramatically accelerate the shift toward a carbon-neutral and economically efficient energy future.

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