Gang HUANG, Fei WU, Chuangxin GUO, 2022. Smart grid dispatch powered by deep learning: a survey. *Frontiers of Information Technology & Electronic Engineering*, 23(5):763-776. https://doi.org/10.1631/FITEE.2000719

Front Inform Technol Electron Eng

Smart grid dispatch powered by deep learning: a survey

Key words: Artificial intelligence; Deep learning; Power dispatch; Smart grid

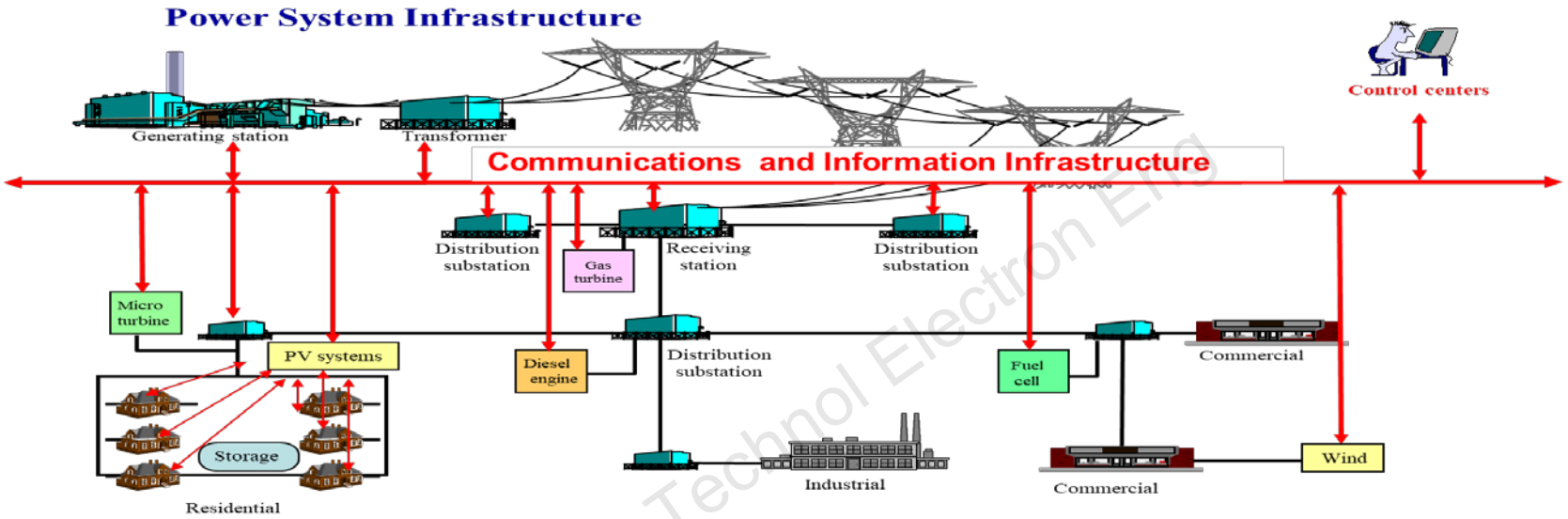
Corresponding author: Gang HUANG
E-mail: huanggang@zju.edu.cn
ORCID: https://orcid.org/0000-0001-8393-6469

Motivation

1. Power dispatch is a core problem for smart grid operations. Due to the complexity of the problem, reliable and computationally efficient solutions are still under development. This issue will become more urgent and complicated as the integration of intermittent renewable energies increases and the severity of uncertain disasters gets worse.
2. With the recent success of artificial intelligence in various industries, deep learning becomes a promising direction for power engineering as well, and the research community begins to rethink the problem of power dispatch. This motivated us to write this article to summarize what has been done already and where deep learning is headed regarding smart grid dispatch.

Front Inform Technol Electron Eng

Smart grid



Item	Smart grid	Conventional power grid
1	Cyber-physical system	Electromechanical system
2	Sensors throughout the network	Few sensors
3	Relatively distributed generators	Relatively centralized generators
4	Automatic monitoring	Manual monitoring
5	More reliable and resilient	Suffering more from failures and blackouts
6	Consumers have many choices	Consumers have few choices

Smart grid benefits



Efficiency: enable greater utilization of generators and lines

Resilience: ensure a more reliable supply of electricity, especially against disasters

Sustainability: permit greater penetration of renewable energy sources

Market-enabling: allow more choices and lower energy bills

Smart grid dispatch

$$\min\ f(x)$$
$$\text{s.t.} \begin{cases} g(x) = 0 \\ h(x) \le 0 \end{cases}$$

Mathematically, smart grid dispatch is an optimization problem. Under different assumptions or for different requirements, smart grid dispatch problems will have different formulations.



Popular formulations

Economic dispatch

$$\min\ c(P_{\mathrm{G}})$$
$$\text{s.t.}\begin{cases} \sum_G P_{\mathrm{G}} - \sum_D P_{\mathrm{D}} = 0, \\ P_{\mathrm{G}}^{\min} \le P_{\mathrm{G}} \le P_{\mathrm{G}}^{\max}, \end{cases}$$

Optimal power flow

$$\min\ c(P_{\mathrm{G}})$$
$$\text{s.t.}\begin{cases} P_{\mathrm{G}} - P_{\mathrm{D}} - \boldsymbol{B\Theta} = 0, \\ -P_{\mathrm{L}}^{\max} \le \boldsymbol{X\Theta} \le P_{\mathrm{L}}^{\max}, \\ P_{\mathrm{G}}^{\min} \le P_{\mathrm{G}} \le P_{\mathrm{G}}^{\max}. \end{cases}$$



Unit commitment

$$\min \sum_t \left(c_1(P_{\mathrm{G},t}) + c_2(u_{\mathrm{G},t}) + c_3(\mathrm{su}_{\mathrm{G},t}) + c_4(\mathrm{sd}_{\mathrm{G},t})\right)$$
$$\text{s.t.}\begin{cases} \sum_G P_{\mathrm{G},t} - \sum_D P_{\mathrm{D},t} = 0, \\ u_{\mathrm{G},t} P_{\mathrm{G}}^{\min} \le P_{\mathrm{G},t} \le u_{\mathrm{G},t} P_{\mathrm{G}}^{\max}, \\ u_{\mathrm{G},t} = u_{\mathrm{G},t-1} + \mathrm{su}_{\mathrm{G},t} - \mathrm{sd}_{\mathrm{G},t}, \\ \sum_t \mathrm{su}_{\mathrm{G},t} \ge \mathrm{SU}_{\mathrm{G}}, \\ \sum_t \mathrm{sd}_{\mathrm{G},t} \ge \mathrm{SD}_{\mathrm{G}}, \end{cases}$$

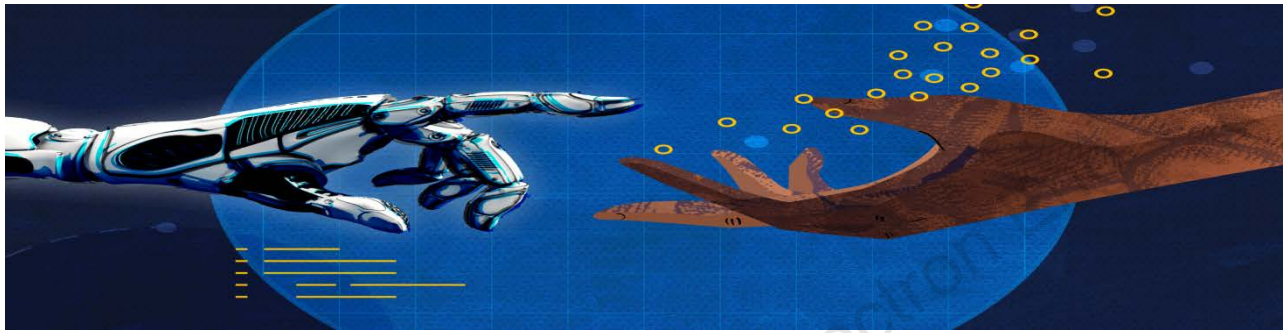
Security-constrained dispatch

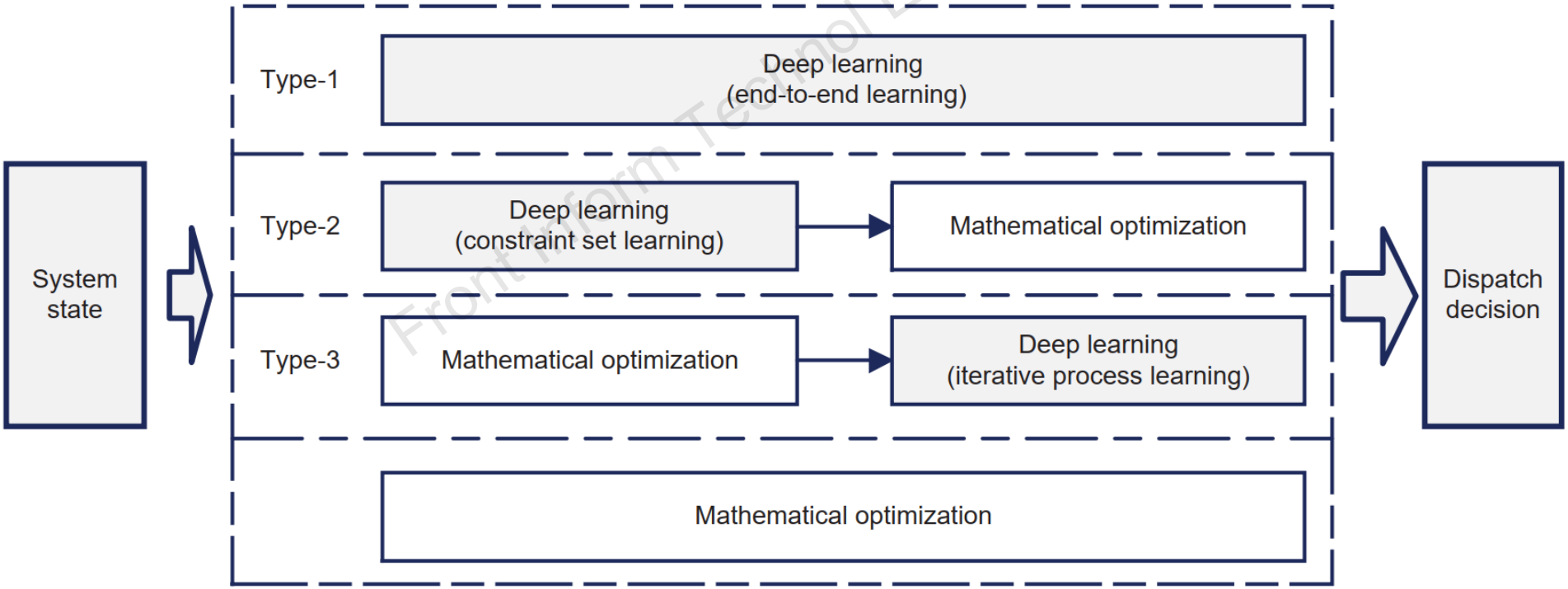
$$\min\ c(P_{\mathrm{G}})$$
$$\text{s.t.}\begin{cases} P_{\mathrm{G}} - P_{\mathrm{D}} - \boldsymbol{B\Theta} = 0, \\ -P_{\mathrm{L},c}^{\max} \le \boldsymbol{X\Theta} \le P_{\mathrm{L},c}^{\max}, \\ P_{\mathrm{G}}^{\min} \le P_{\mathrm{G}} \le P_{\mathrm{G}}^{\max}, \end{cases}$$

$$\min\ c(P_{\mathrm{G},c})$$
$$\text{s.t.}\begin{cases} P_{\mathrm{G},c} - P_{\mathrm{D}} - \boldsymbol{B\Theta}_c = 0, \\ -P_{\mathrm{L},c}^{\max} \le \boldsymbol{X\Theta}_c \le P_{\mathrm{L},c}^{\max}, \\ P_{\mathrm{G}}^{\min} \le P_{\mathrm{G},c} \le P_{\mathrm{G}}^{\max}. \end{cases}$$

Front Inform Technol Electron Eng

Deep learning solutions





Front Inform Technol Electron

Representative publications

We have provided our taxonomy of all the deep learning solutions which can be divided into three categories (end-to-end learning, constraint set learning, and iterative process learning). Representative publications are listed below (the details are referred to our paper):

Front Inform Technol Electron Eng

Category	Subcategory	Publications
End-to-end learning		Yin et al. (2018, 2020), Fioretto et al. (2019), Pan et al. (2019, 2021a, 2021b), Chatzos et al. (2020), Duchesne et al. (2020a), Owerko et al. (2020), Venzke et al. (2020a), Yan and Xu (2020), Zamzam and Baker (2020), Zhao et al. (2020), Zhou YH et al. (2020)
Constraint set learning	Identify constraints	Ardakani and Bouffard (2018), Deka and Misra (2019), Chen YZ and Zhang (2020), Yang et al. (2020b)
	Replace constraints	King et al. (2016), Liu TJ et al. (2020), Venzke et al. (2020b), Yang et al. (2020a), Hu et al. (2021)
Iterative process learning	Initialize solvers	Diehl (2019), Jamei et al. (2019), Biagioni et al. (2020), Chen LJ and Tate (2020)
	Replace solvers	Baker (2020), Robson et al. (2020)

Challenges

1. Data availability, security, and privacy: Very few electric power system datasets are publicly available at the present time, and this raises an obstacle for deep learning experts. In addition, how to perform deep learning without sacrificing the data security and privacy remains a challenge.
2. Model robustness and explainability: Power systems are critical infrastructure and are very sensitive, so robust deep learning methods are necessary. Moreover, deep learning methods will always generate a solution, but this is not at all an advantage in fields like smart grids if we cannot explain the solution they provide.

Front Inform Technol Electron Eng