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Large-Scale Integration of Renewable Power Sources into the Vietnamese Power System

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Abstract

The Vietnamese Power system is expected to expand considerably in upcoming decades. However, pathways towards higher shares of renewables ought to be investigated. In this work, we investigate a highly renewable Vietnamese power system by jointly optimising the expansion of renewable generation facilities and the transmission grid. We show that in the cost-optimal case, highest amounts of wind capacities are installed in southern Vietnam and solar photovoltaics (PV) in central Vietnam. In addition, we show that transmission has the potential to reduce levelised cost of electricity by approximately 10%.

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Keywords: Vietnamese Power System;Renewable Energy;Power System Expansion;Wind Power;Solar Power

1. Introduction

Power systems are transforming world wide. The transformation from conventional dispatchable power generation from fossil sources towards power generation from the renewable sources of mainly wind, solar and hydro is driven by goals of sustainability and reduction of climate gas emissions to mitigate climate change. However, renewable power generation depends on the weather and therefore has strongly fluctuating feed-in profiles which, in turn, make the system integration of renewables difficult. Among solutions to integrate high shares of renewable into power systems, are: i) optimising the mix of generation from different renewable sources [1, 2, 3, 4, 5, 6] ii) storage [7, 8] iii) dispatchable backup power [9, 10] iv) sector coupling [11, 12] v) transmission grid extensions [13, 14] vi) controllable

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hydro power [15] vii) system-friendly renewables [16, 17] or viii) demand-side management [18, 19].
In developing countries such as Vietnam, power demand grows strongly and a reliable energy supply has imminent importance for stable economic growth and prosperity. The Vietnamese demand for electricity is growing at an average speed of 7-8% per year and the peak demand is estimated to reach 42.1 GW by 2020 and 90.7 GW by 2030 [20]. At present, Vietnam has mainly exploited thermal and hydro power resources and coal as major energy carrier is being imported from abroad. However, the number of thermal power plants is likely to be limited in the future due to concerns raised by environmental pollution and dependency on imports. Therefore, the importance of renewable energy sources such as wind, solar, tidal, biomass will play an increasingly important role for Vietnam.
The national energy development vision until 2050, which was approved by the Vietnamese Prime Minister, emphasises the role of renewable energy sources in particular. It is expected that by 2050, 43% of Vietnams electricity will be provided from renewable sources. Expectations about installed wind power capacity are 800 MW in 2020, 2,000 MW in 2025 and around 6,000 MW by 2030. For solar energy, predicted numbers of installed capacities are 850 MW (by 2020) 4,000 MW (2025) and 12,000 MW (2030). In addition, biomass will contribute about 1% of entire generation by 2020, 1.2% by 2025 and 2.1% by 2030 [21].
In 2014, the Vietnamese electricity production of 145.5 TWh was mainly supplied by hydro power (38%, not including small hydro), CCGT (31%) and Coal (26%). The dominance of those three sources was also reflected by their shares in overall installed capacities of 34 GW, comprising hydro (40%, not including small hydro), gas (22%) and coal (29%). However, the Vietnamese power development plan predicts total installed capacities by 2030 of 116 GW with shares of hydro (18%) and gas (17%) shrinking and coal (50%) and renewables (10%) growing [22].
In this paper, we investigate the optimal mix of renewables from wind and photovoltaics distributed among the highest voltage substations of a simplied future Vietnamese power system.
Similar studies of the power system transition of developing countries have been performed for a variety of countries such as Iran [23] and also Vietnam [24], but in the latter case with a strong focus on conventional generation technologies and without including time-dependent resource availabilities.

2. Methodology

We use a simplified version of the Vietnamese power system, where loads and generation are connected to the closest existing highest voltage substation. The topology of the resulting network is shown in Fig. 1. The model is formulated as a linear optimisation model that minimises total system cost. The objective reads

$$\min_{g,G,f,F} \left(\sum_{n,s} c_{n,s} G_{n,s} + \sum_{l} c_l F_l + \sum_{n,s,t} o_{n,s} g_{n,s}(t) \right), \tag{1}$$

where $c_{n,s}$ is the investment cost for generation capacity, c_l is the investment cost for transmission capacity, $o_{n,s}$ is the marginal cost of energy generation, $G_{n,s}$ and F_l are the capacities of generators and transmission links and $g_{n,s}$ is the time series of generation. The index n runs over all nodes and s over considered technologies (wind and solar PV).
In addition to the objective, multiple constraints have to be satisfied. To ensure stable power system operation, generation and demand need to match in space and time:

$$\sum_{s} g_{n,s}(t) - d_n(t) = \sum_{l} K_{n,l} f_l(t) \forall n, \tag{2}$$

where $d_n(t)$ is the demand, K is the incidence matrix of the network and f_l the flow over link l.
The dispatch of a generator $g_{n,s}(t)$ is constrained by the corresponding generator constraint $G_{n,s}$ multiplied with the corresponding hourly capacity factor $\bar{g}_{n,s}(t)$:

$$0 \leq g_{n,s}(t) \leq \bar{g}_{n,s}(t) G_{n,s} \forall n. \tag{3}$$

Flows between nodes can not exceed transmission limits,

$$|f_l(t)| \leq F_l \forall l, \tag{4}$$