From multi-decadal energy planning to hourly power dispatch: evaluating the reliability of energy projections in the Southern African Power Pool

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[1] ABSTRACT

Development pathways for Sub-Saharan Africa project a substantial increase in population and living standards. To quantify the transmission lines overload and the transmission generation deficits in the SAPP region, we inform a power system simulation model, PowNet (see [1]), with energy development pathways from a long-term energy system planning model, OSeMOSYS-TEMBA (see [2]). We assess the transmission lines overload and the power generation deficits in 2025 and 2030 under three climate policy scenarios: no climate policy, and constrained to 2.0˚C and 1.5˚C warming forcing emissions to a consistent pathway.

[2] RESEARCH OBJECTIVES

- To evaluate differences in power operations between energy and power system models.
- To examine the power generation deficit and the overloading of the transmission lines.
- To suggest potential technical solutions.

[3] METHODOLOGY

Downscaling in time and space using a power system model, PowNet, forced with input derived from an energy system planning model, OSeMOSYS-TEMBA.
The power system component of the energy system is simulated at an hourly resolution using PowNet, with an updated power grid representation to evaluate existing and future transmission line strains that could impact load reliability and stability in different specific years of interest.

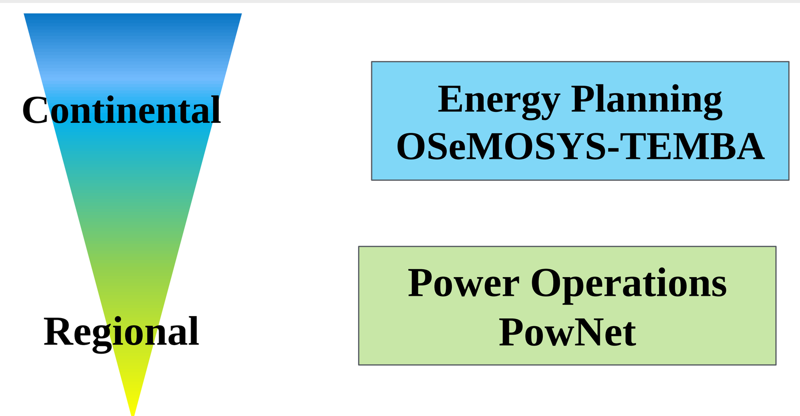


Figure 1. Dowscaling approach.

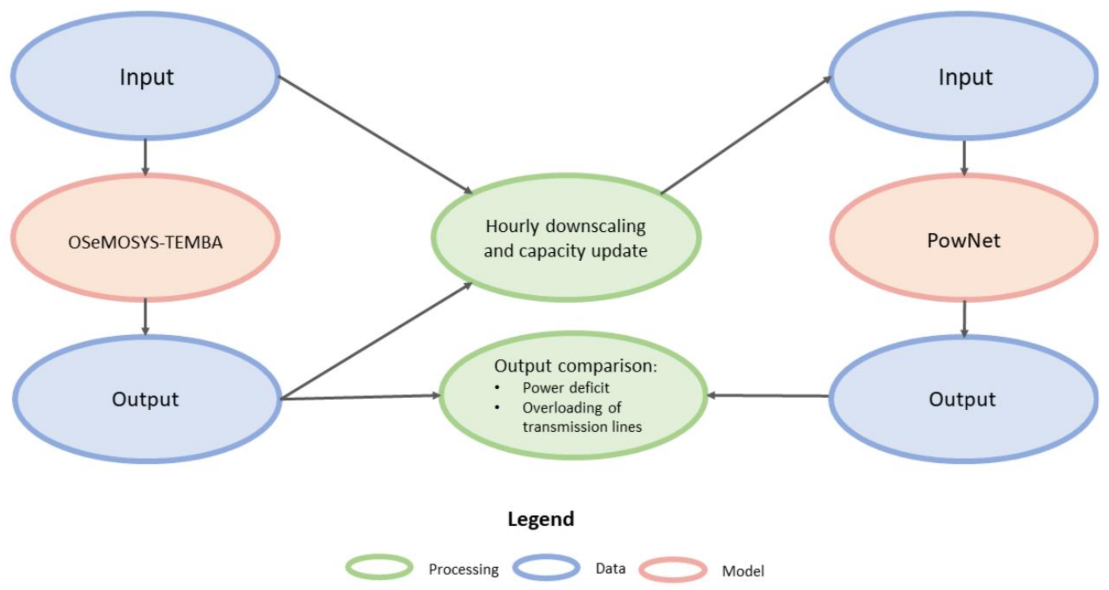


Figure 2. Methodology framework.

- The energy system model produces among his output the capacity expansion, i.e., the new capacity to be installed in the power system;
- the input and the output of the energy system model are used to prepare the input of the power system model;
- the power system model simulates the power system in different specific years of interest;
- the outputs of the power and the energy system model are used to examine how different capacity expansion plans result in power deficit and strain existing and future transmission lines.

[4] CASE STUDY

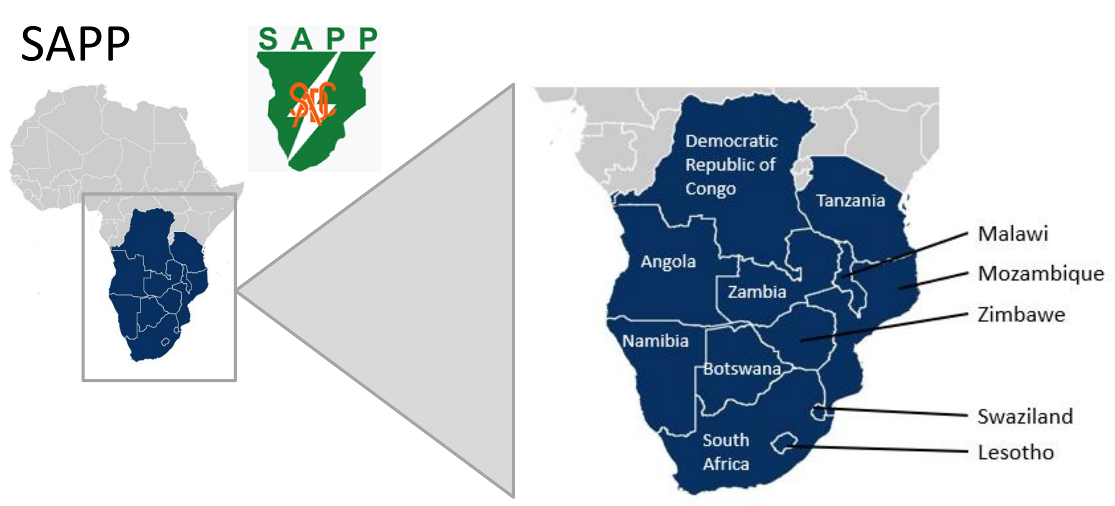
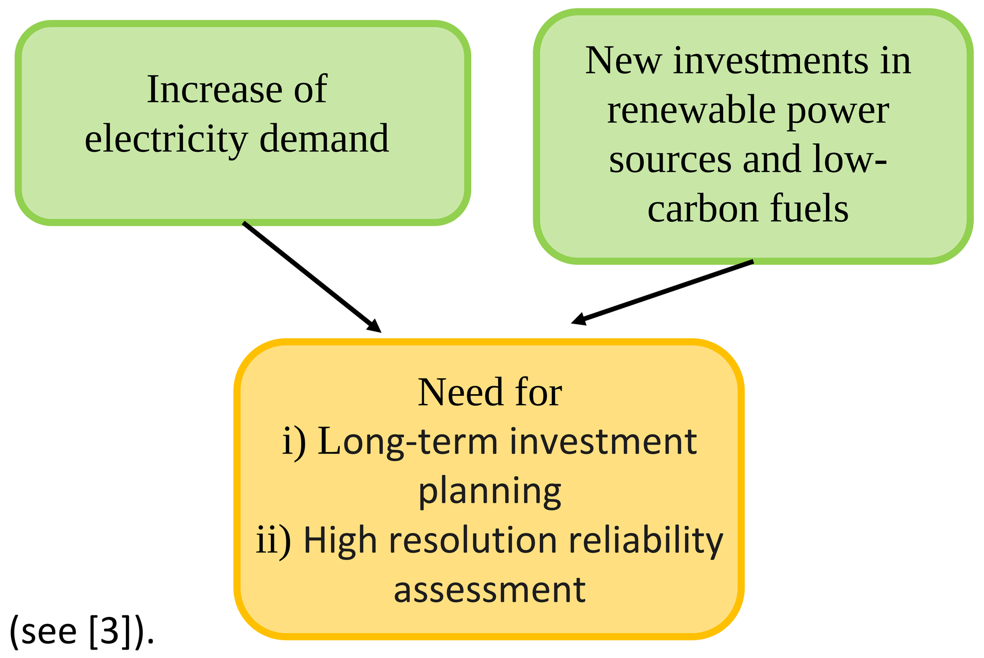


Figure 3. Modelled energy system: the Southern African Power Pool (see [3]).



[5] RESULTS

Model configuration	Scenario	Year	Power deficit (%)	P(violation)
Benchmark	Refer	2025	0.26	0.06
Benchmark	2.0 °C	2025	0.78	0.06
Benchmark	1.5 °C	2025	0.76	0.06
Benchmark	Refer	2030	0.58	0.07
Benchmark	2.0 °C	2030	1.23	0.08
Benchmark	1.5 °C	2030	1.22	0.08
With reserve margin	Refer	2030	1.07	0.07
With reserve margin	2.0 °C	2030	1.54	0.08
With reserve margin	1.5 °C	2030	1.35	0.08

Table 1. Summary results. Percentage of power deficit in the annual generaiton mix and hourly probability of violation of the transmission lines. The the most critical simulations are those performed in 2030, particularly under the 2.0°C and 1.5°C scenarios with reserve margin constraints

[5] RESULTS

2030 without reserve margin constraints, scenario 1.5°C.

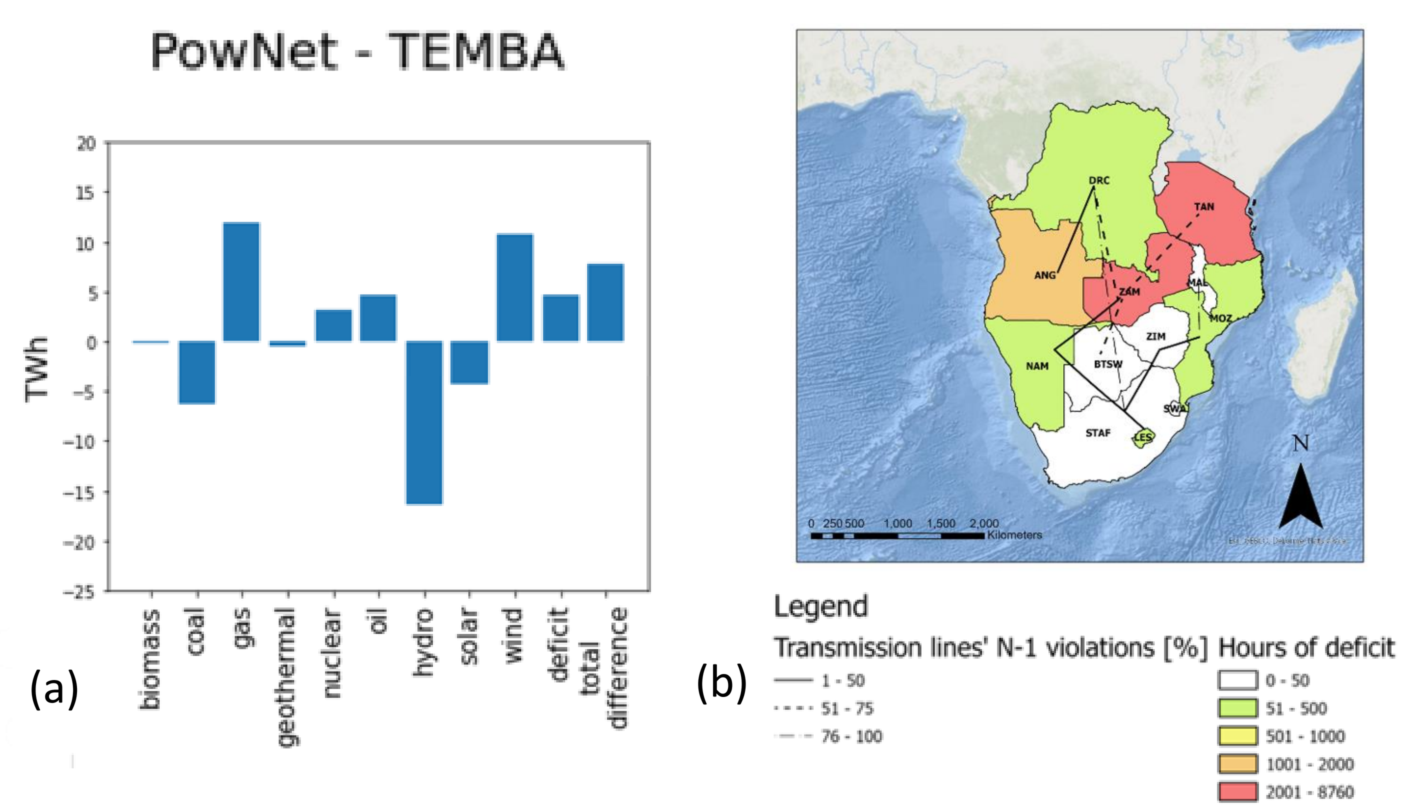


Figure 4. In panel (a) annual output differences of OSeMOSYS-TEMBA and PowNet. Power generation from coal decreases in comparison to OSeMOSYS-TEMBA. In panel (b) Power deficit and transmission lines' overloading. The power generated is insufficient to meet the demand, and the power generation deficit is distributed among several countries.

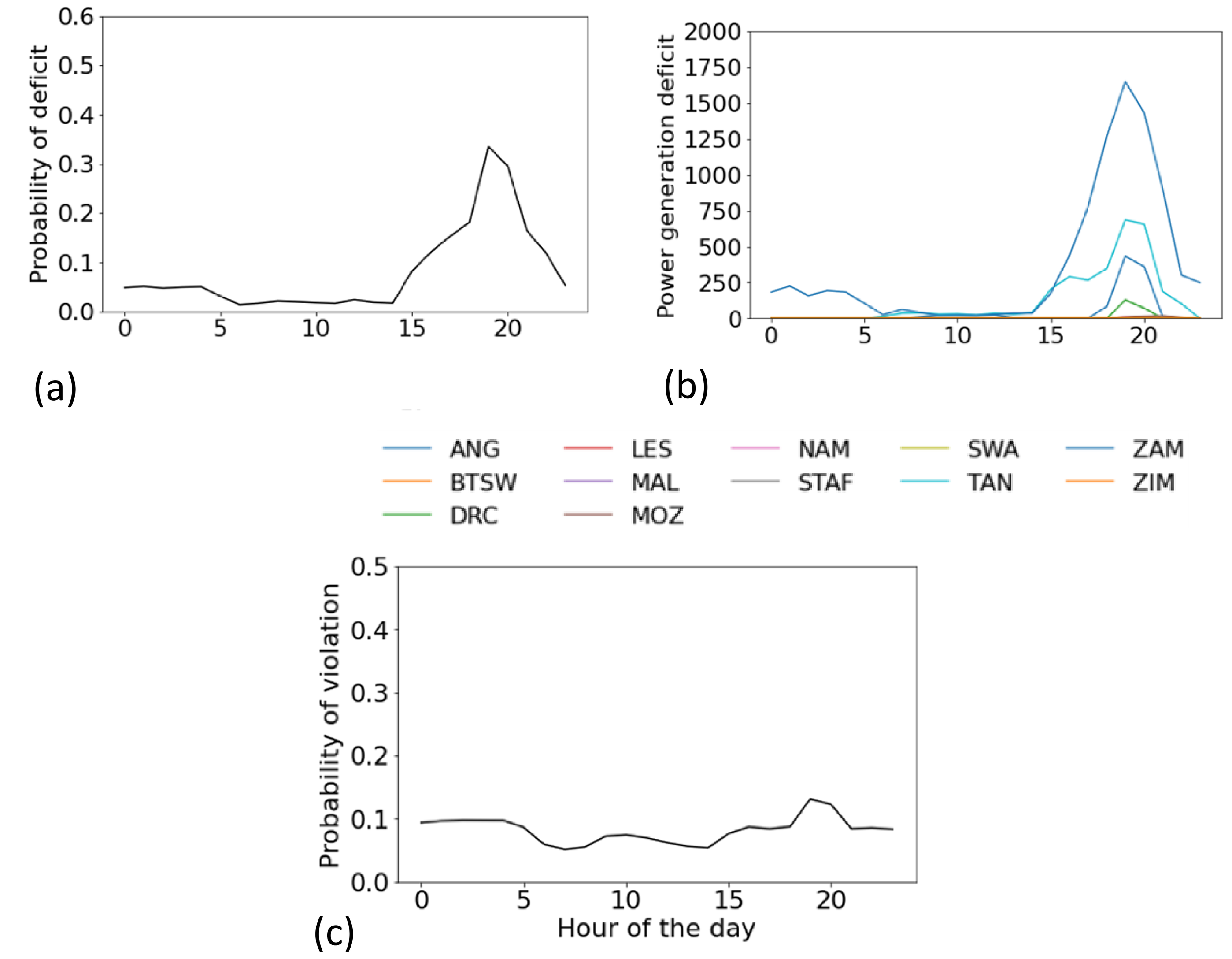


Figure 5. In panel (a) mean hourly probability of deficit. In panel (b) mean hourly deficit for each country. In panel (c) mean hourly probability of violation of the transmission lines. The critial hours are during the evening, when the probability of power generation deficit and the probability of violation of transmission lines are high.

2030 with reserve margin constraints , scenario 1.5°C.

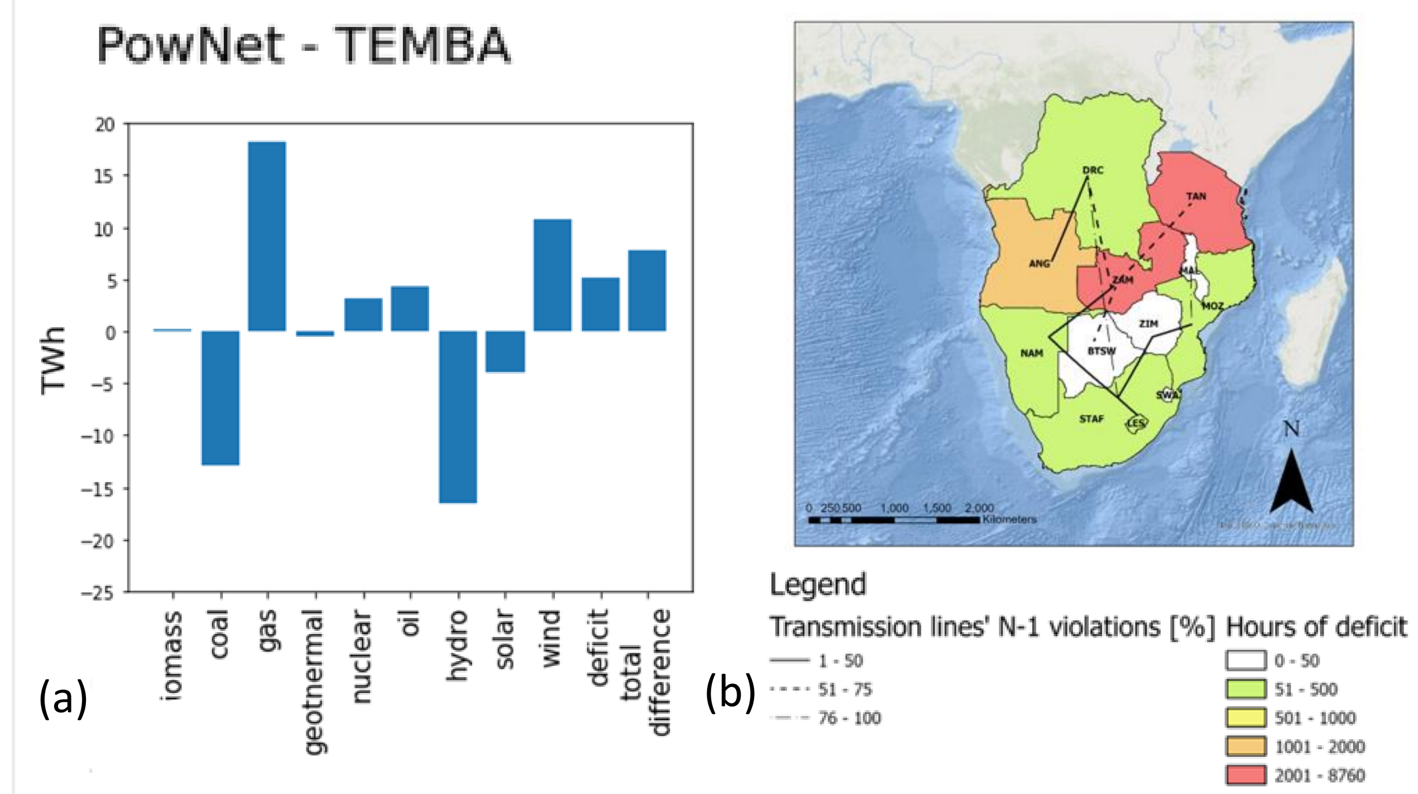


Figure 7. In panel (a) annual output differences of OSeMOSYS-TEMBA and PowNet. Power generation from coal decreases in comparison to both OSeMOSYS-TEMBA and the simulation computed without reserve margin contriants. In panel (b) Power deficit and transmission lines' overloading. The power generation deficit is higher respect to the simulation computed without reserve margin contraints and most of the countries are unable to meet their power demand at all times.

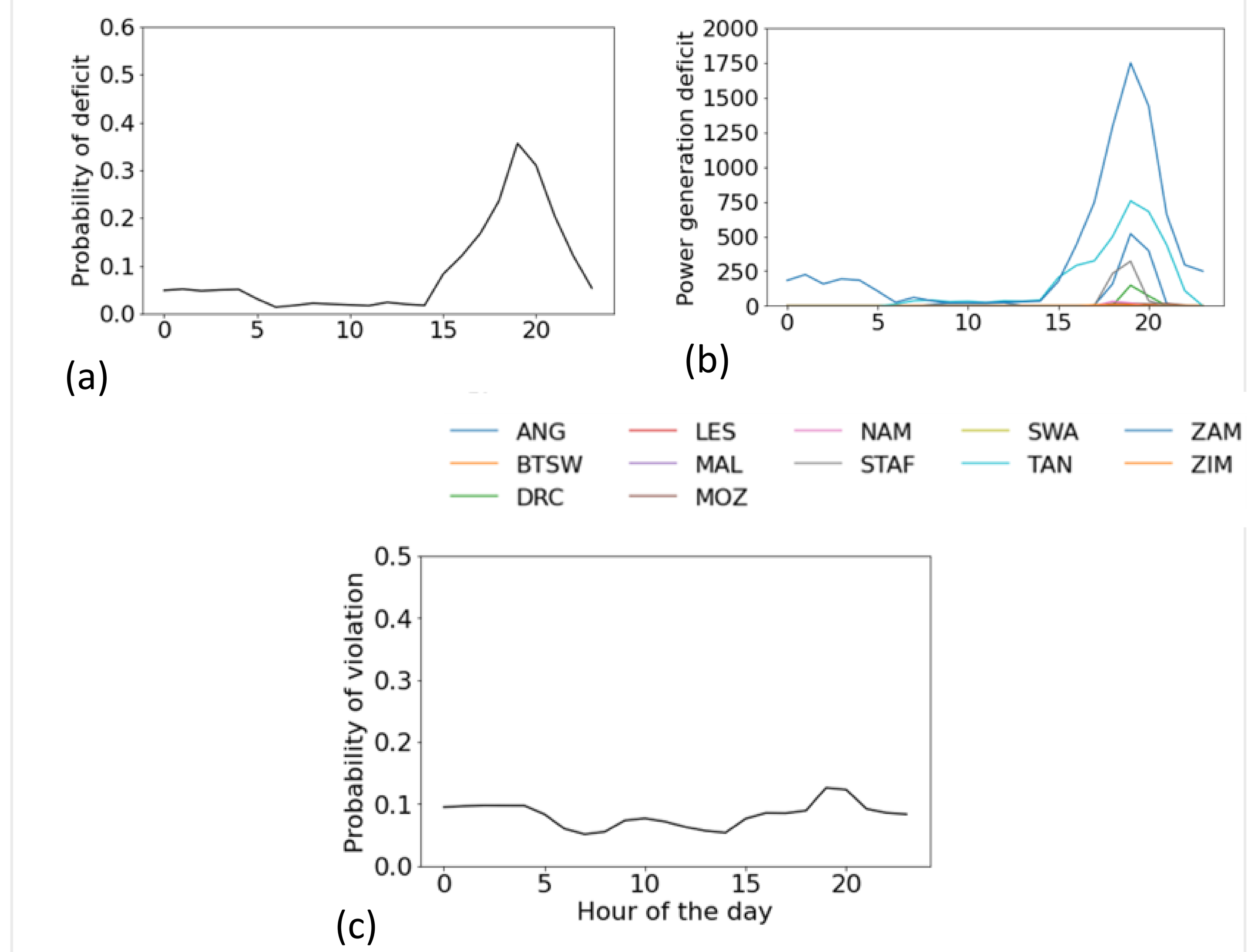


Figure 8. In panel (a) mean hourly probability of deficit. In panel (b) mean hourly deficit for each country. In panel (c) mean hourly probability of violation of the transmission lines. The critial hours are during the evening, when the probability of power generation deficit and the probability of violation of transmission lines are high.

[6] HIGHLIGHTS

- **Deficit**: during the evening, when the solar generation decreases and the power system cannot quickly compensate with generation from other resources.
- Power system downscaling allows to assess **reliability of capacity expansion** plan at high resolution
- Capacity needs to increase in **Democratic Republic of the Congo, South Africa, Tanzania, and Zambia**

REFERENCES

1. Chowdhury et al. Pownet: A network-constrained unit commitment/economic dispatch model for large-scale power systems analysis, 2020.
2. Pappis et al. Energy projections for african countries, 2019.
3. SAPP. Sapp annual article, 2021.

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