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Complementarity of Solar and Wind Energy Sources in Brazil

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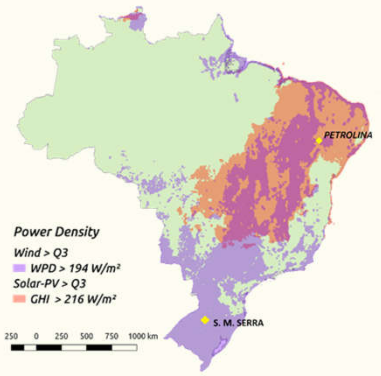
ABSTRACT

One of the most promising solutions for ensuring the safety and reliability of electricity supply, optimizing the grid, and matching local supply and demand is the hybridization of two or more power sources in a single generation plant. Hybridization will also help to cope with the observed growth of intermittent generation technologies such as the solar and wind, whose resources are still untapped in the energy mix. This hybridization mix of solar and wind energy with hydropower is the focus of this study since hydropower is the backbone of the Brazilian electricity generation sector. As of December 2018, 66.6% of Brazil electrical energy demand was met by large-scale hydroelectric power (BEN, 1019). While hydroelectricity will no doubt feature heavily in Brazil's electricity mix, the Ministry of Mines and Energy aims, along with significant backing from the private sector, to diversify the power mix in order to reduce the risk of power shortages caused by droughts and thereby increasing energy security. The government strategy for diversification and energy security has been to increase the share of thermal, nuclear, as well as alternative renewable energy such as biomass, onshore wind, and PV solar. According to official Brazilian sources (BEN, 2019), wind power represents 7.6% of the national electricity generation matrix, with robust growth of 14% between 2017-18 compared to traditional sources. Although representing less than 1.5% of the energy mix, the solar power generation, consisting primarily of large photovoltaic projects and distributed systems, showed the largest growth compared to all other energy resources, more than 300% in the same period. This study uses global irradiance data measured at the Petrolina (PTR) and São Martinho da Serra (SMS) radiometric stations from the Baseline Surface Radiation Network - BSRN (https: //bsrn.awi. from /stations/listings/). Wind data were collected from the SONDA anemometric towers (http://sonda.ccst.inpe.br/), which operate in conjunction with these BSRN radiometric stations. The period of data acquisition was from 2005 to 2016. These locations were selected to represent some of Brazil's main climatological sub regions. The study has shown a variable but representative degree of smoothing of the final energy produced by employing different compositions of the solar-wind assortment for each one of the studied location. The optimum share of solar to wind mix depends not only on the region but on time scales of interest, confirming the importance of spatial planning of energy mixes to improve grid reliability



Overlapping regions above Q3 percentile for wind and solar power density in Brazil

METHODS

To evaluate the performance of hybrid projects for different solar fractions we used the metrics shown in Table 1. Nonetheless other indexes could be used depending on the timescale and local specific constraints.

Table 1: Metrics adopted for hybrid projects evaluation.

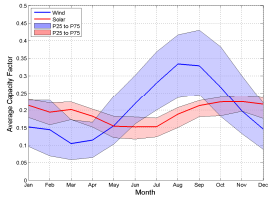
Metrics	
Maximum average monthly CF	CF_{AVGmax}
Minimum monthly CF Stand. Deviation	CF_{SDmin}
Nbr of days below 50% CF	N_{Days50}
Nbr of hours below 10% CF	$N_{Hours10}$

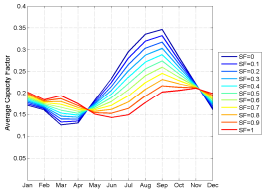
Solar tracker at Petrolina (PTR) BSRN site

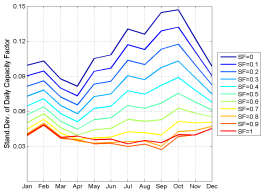
Wind mast at São Martinho da Serra (SMS) BSRN site

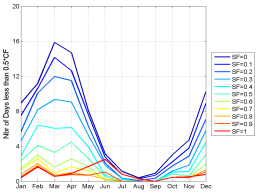
RESULTS

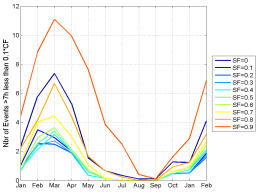
PTR



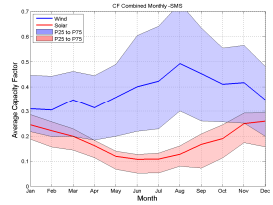


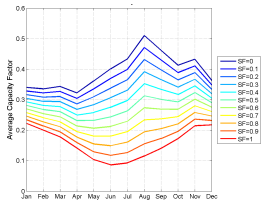


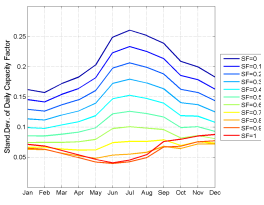


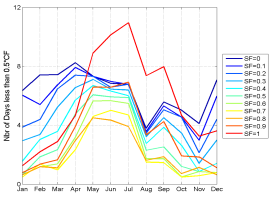


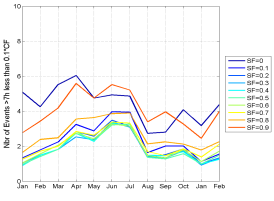
SMS











Monthly average CF and P25-P75 interval for solar and wind projects separately for PTR and SMS

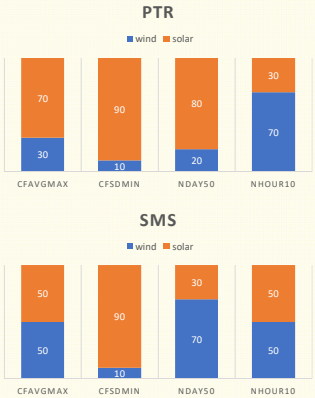
Average combined CF at monthly time scales for different solar fractions SF for PTR and SMS

Standard deviation daily CF at monthly time scales for PTR and SMS

Mean number of days in a month with less than 50% of annual mean CF for PTR and SMS

Mean number of events in a month of 7 consecutive hours with less than 10% of annual mean CF

SUMMARY



Best compromise Solar Fraction (SF) for different metrics at each site.

CONCLUSIONS

- Average solar CF varies from 0.09 to 0.22 while average wind CF varies from 0.12 to 0.52.
- The observed lag between wind and solar CF cycles are around 3 months for PTR (absence of complementary) and 5 months for SMS (strong complementarity) on the seasonal scale.
- Solar power presents a much lower variability on all but hourly time scales when compared to wind power. This is not surprisingly due to nature of insolation in tropical regions and justify the tendency towards a high share of solar (SF=90%) to minimize daily variability (CF_{SDmin})
- The CF_{AVGmax} depends highly on wind and solar seasonal profiles, showing large differences from northeastern (SF=70%) to southern (SF=50%) regions.
- The number of days below 50% of average (N_{day50}) presented larger differences from regions, favoring solar in PTR (SF=80%) and wind in SMS (SF=30%).
- Remarkably, results indicate that any mix from SF=20% to 80% in both sites reduces significantly the events of 7+ hours below 10% CF (N_{hour10}), delivering higher reliability to grid.

FORTHCOMING RESEARCH

The next steps involves expanding the analysis for other sites in Brazil with different climates. From the methodology side we plan to include new metrics and correlate solar-wind power to local demand curves and scale the hybrid plant to meet average power demand. This can includes lagged correlations and optimization of solar panel orientation that maximizes wind-solar hourly complementarity.

References

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[2] B. Franc¸ois, M. Borga, J. D. Creutin, B. Hingray, D. Raynaud, and J. F. Sauterleute. Complementarity between solar and hydro power: Sensitivity study to climate characteristics in Northern-Italy. Renewable Energy, 86:543–553, 2016

Acknowledgements

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