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Power Systems Laboratory

Analysis of the Sizing Factor Inverter in Brazilian Regions of Tropical Semiarid Climate

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OUTLINE

- ✓ Introduction
- ✓ Photovoltaic System Model
- ✓ Merit Indexes
- ✓ Simulation Methodology
- ✓ Simulation Results
- ✓ Conclusions

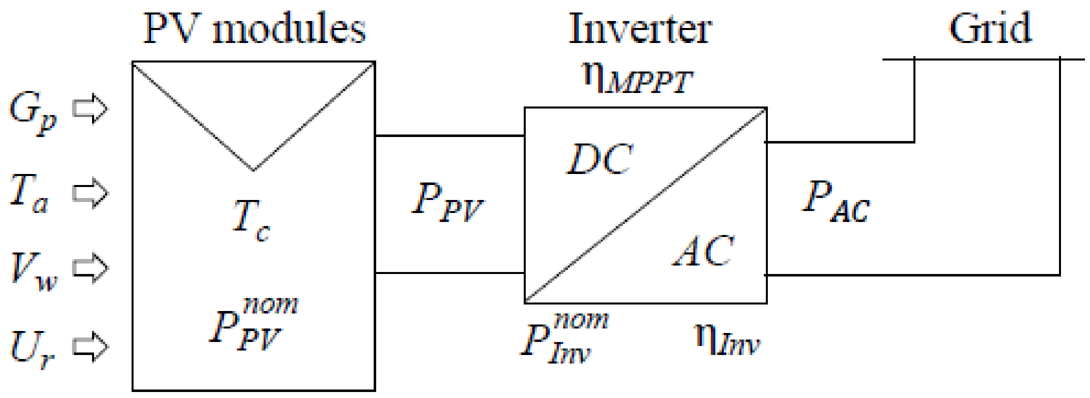
INTRODUCTION

- ✓ Solar energy system designers frequently opt for a photovoltaic generator power higher than the inverter power, i.e., they consider the Sizing Factor Inverter (SFI) lower than the unit;
- ✓ Several models for the prediction of SFI have been proposed in the literature:
  - ➢ These models disregard the effect of climatic factors such as relative humidity and wind speed on the performance of photovoltaic (PV) cells;
- ✓ Development of a methodology of prediction of the SFI;
- ✓ Localities of semiarid tropical climate;
- ✓ Effect of climatic factors, like wind speed and relative humidity of the air in the performance of PV modules.

INTRODUCTION

- ✓ Methodology:
  - ➢ Analysis of bibliographic works that include the modeling of PV modules, inverters and the determination of SFI;
  - ➢ Study of impacts of ambient temperature, solar irradiance, wind speed and relative humidity on calculation of operating temperature of PV cells;
  - ➢ Research of climatological databases of Brazilian Northeastern semiarid regions;
  - ➢ Development of simulation programs and analysis of results;
- ✓ Contributions:
  - ➢ Analysis of sensibility of inverter efficiency and merit indexes of PV systems to variations in SFI;
  - ➢ Establishment of a range of SFI values that result in better merit indexes for locations with semiarid tropical climate.

PHOTOVOLTAIC SYSTEM MODEL



Simplified representation of a grid-connected PV system and simulation variables.

- ✓ I. PV Operating Cell Temperature;
- ✓ II. PV Output Power;
- ✓ III. Inverter Eficciency;
- ✓ IV. AC Output Power.

- ✓ PV Operating Cell Temperature:

$$T_c = T_a + G_p \cdot K_t \, , \qquad (1)$$

$$T_c = T_a + \frac{(T_{NOCT} - 20)}{800} \cdot \frac{9.5G_p}{1 + 3.8V_w} \cdot \left(1 - \frac{n_{module}}{0.9}\right), \qquad (2)$$

$$T_c = 0.95T_a + 0.03G_p - 1.51V_w + 0.16U_r + 0.10 \, . \qquad (3)$$

PHOTOVOLTAIC SYSTEM MODEL

✓ PV Output Power:

$$P_{MPP} = P_{PV}^{nom} \cdot \frac{G_p}{1{,}000} \cdot [1 - \gamma_{MP} \cdot (T_c - 25)] \,, \quad (4)$$

$$P_{PV} = P_{PV}^{nom} \cdot \frac{G_p}{1{,}000} \cdot [1 - \gamma_{MP} \cdot (T_c - 25)] \cdot n_{module} \,. \quad (5)$$

✓ Inverter Eficciency:

$$n_{Inv} = \frac{p_{normal}}{p_{normal} + k_0 + k_1 p_{normal} + k_2 {p_{normal}}^2} \,, \quad (6)$$

$$k_0 = \frac{1}{9} \cdot \frac{1}{n_{Inv100\%}} - \frac{1}{4} \cdot \frac{1}{n_{Inv50\%}} + \frac{5}{36} \cdot \frac{1}{n_{Inv10\%}} \,, \quad (7)$$

$$k_1 = -\frac{4}{3} \cdot \frac{1}{n_{Inv100\%}} + \frac{33}{12} \cdot \frac{1}{n_{Inv50\%}} - \frac{5}{12} \cdot \frac{1}{n_{Inv10\%}} - 1 \,, \quad (8)$$

$$k_2 = \frac{20}{9} \cdot \frac{1}{n_{Inv100\%}} - \frac{5}{2} \cdot \frac{1}{n_{Inv50\%}} + \frac{5}{18} \cdot \frac{1}{n_{Inv10\%}} \,. \quad (9)$$

PHOTOVOLTAIC SYSTEM MODEL

- ✓ PV Output Power:

$$
\begin{cases}
P_{AC} = P_{Inv}^{nom} \ \text{if} \ P_{AC} \geq P_{Inv}^{nom}\,, & (10) \\
P_{AC} = 0 \ \text{if} \ P_{PV} \leq (k_0 \cdot P_{Inv}^{nom})\,, & (11) \\
P_{AC} = p_{normal} \cdot P_{Inv}^{nom} \ \text{if} \ (k_0 \cdot P_{Inv}^{nom}) \leq P_{AC} \leq P_{Inv}^{nom} & (12)
\end{cases}
$$

MERIT INDEXES

- ✓ Productivity:

$$Y_F = \frac{\int_{t_1}^{t_2} P_{AC}\, dt}{P_{PV}^{nom}}\,. \qquad (13)$$

- ✓ Performance Ratio:

$$PR = \frac{Y_F}{\frac{\int_{t_1}^{t_2} G_{plane}\, dt}{1{,}000}}\,. \qquad (14)$$

SIMULATION METHODOLOGY

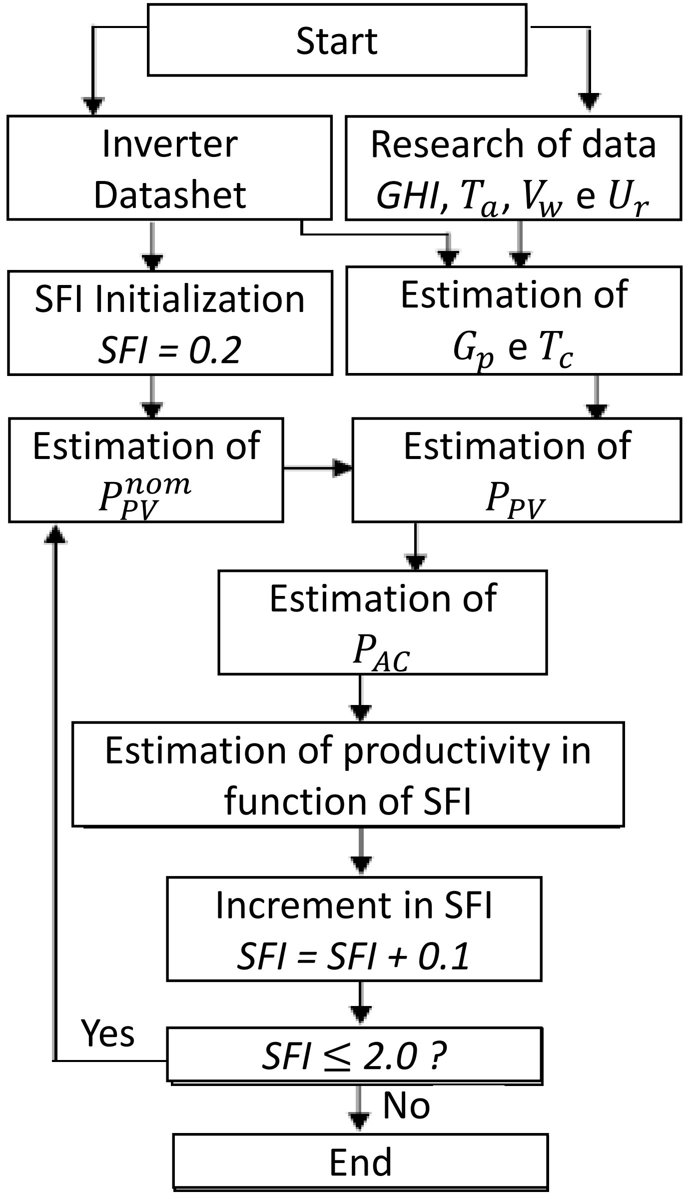


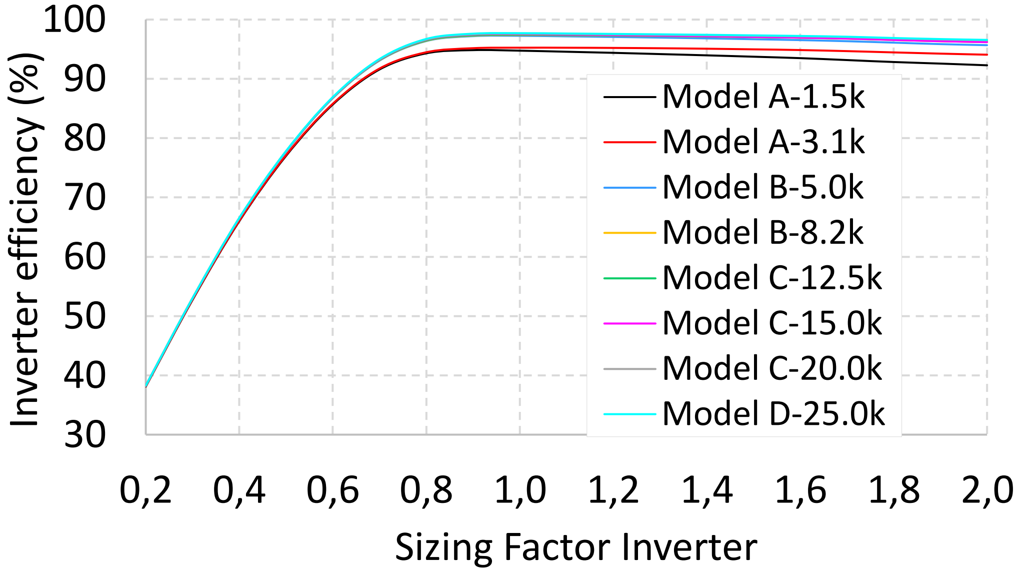
TABLE I. NORTHEASTERN CITIES IN BRAZILIAN SEMIARID

State	City	Latitude
AL	Pão de Açúcar	09°44' S
AL	Piranhas	09°36' S
BA	Euclides da Cunha	10°30' S
BA	Uauá	09°50' S
CE	Quixadá	04°58' S
CE	Quixeramobim	05°11' S
PB	Itaporanga	07°19' S
PB	Patos	07°04' S
PE	Petrolina	09°23' S
PE	Serra Talhada	07°57' S
PI	Picos	07°04' S
PI	São João do Piauí	08°20' S
RN	Caicó	06°27' S
RN	Mossoró	04°54' S
PI	Carira	10°21' S
PI	Poço Verde	10°42' S

SIMULATION METHODOLOGY

TABLE II. ELECTRICAL PARAMETERS OF INVERTERS USED IN SIMULATIONS

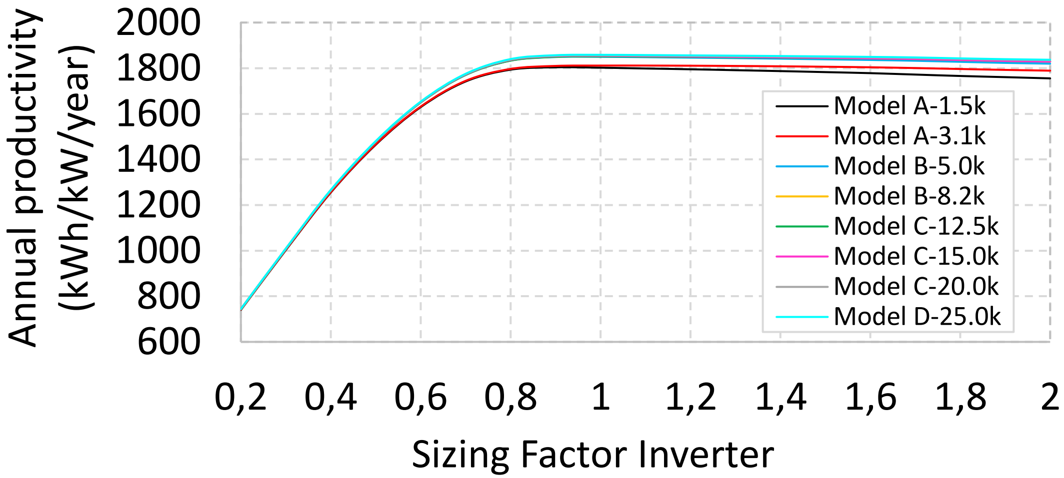
Lines: A and B				
Electrical Parameters	***Model A-1.5k***	***Model A-3.1k***	***Model B-5.0k***	***Model B-8.2k***
AC nominal power (W)	1,500	3,100	5,000	8,200
Efficiency at 10% of P*nom*	0.897	0.933	0.948	0.960
Efficiency at 50% of P*nom*	0.955	0.961	0.979	0.980
Efficiency at 100% of P*nom*	0.959	0.952	0.979	0.977
MPPT efficiency	> 0.999			
Lines: C and D				
Electrical Parameters	***Model C-12.5k***	***Model C-15.0k***	***Model C-20.0k***	***Model D-25.0k***
AC nominal power (W)	12,500	15,000	20,000	25,000
Efficiency at 10% of P*nom*	0.961	0.960	0.969	0.970
Efficiency at 50% of P*nom*	0.980	0.981	0.981	0.982
Efficiency at 100% of P*nom*	0.978	0.981	0.980	0.982
MPPT efficiency	> 0.999			



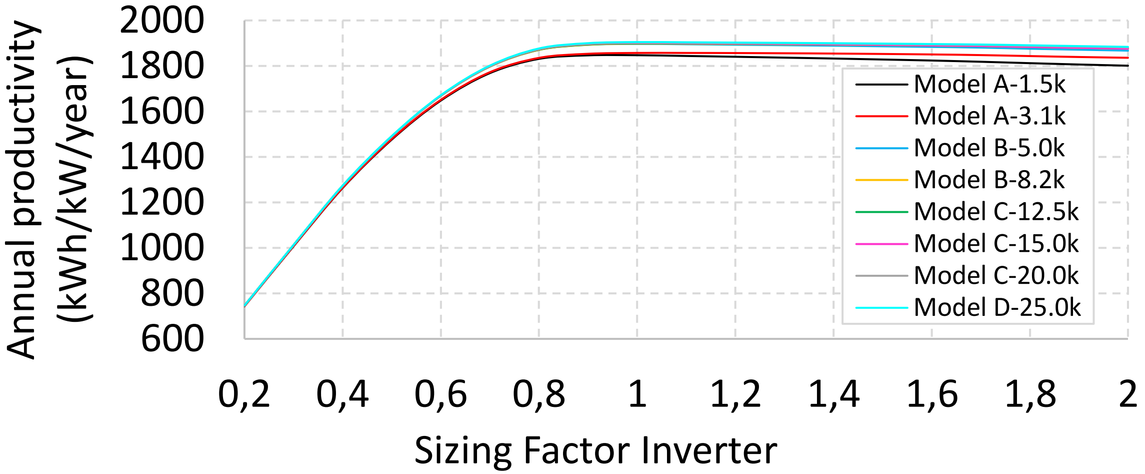
Inverter efficiency in function of SFI

SIMULATION RESULTS

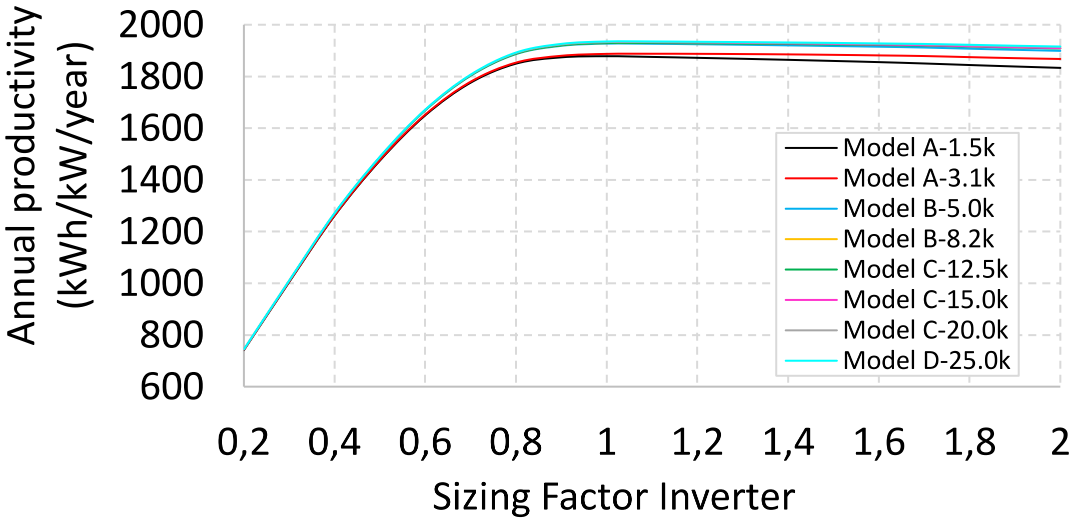
✓ Annual Productivity:



Annual productivity, using (1) to calculate T_c



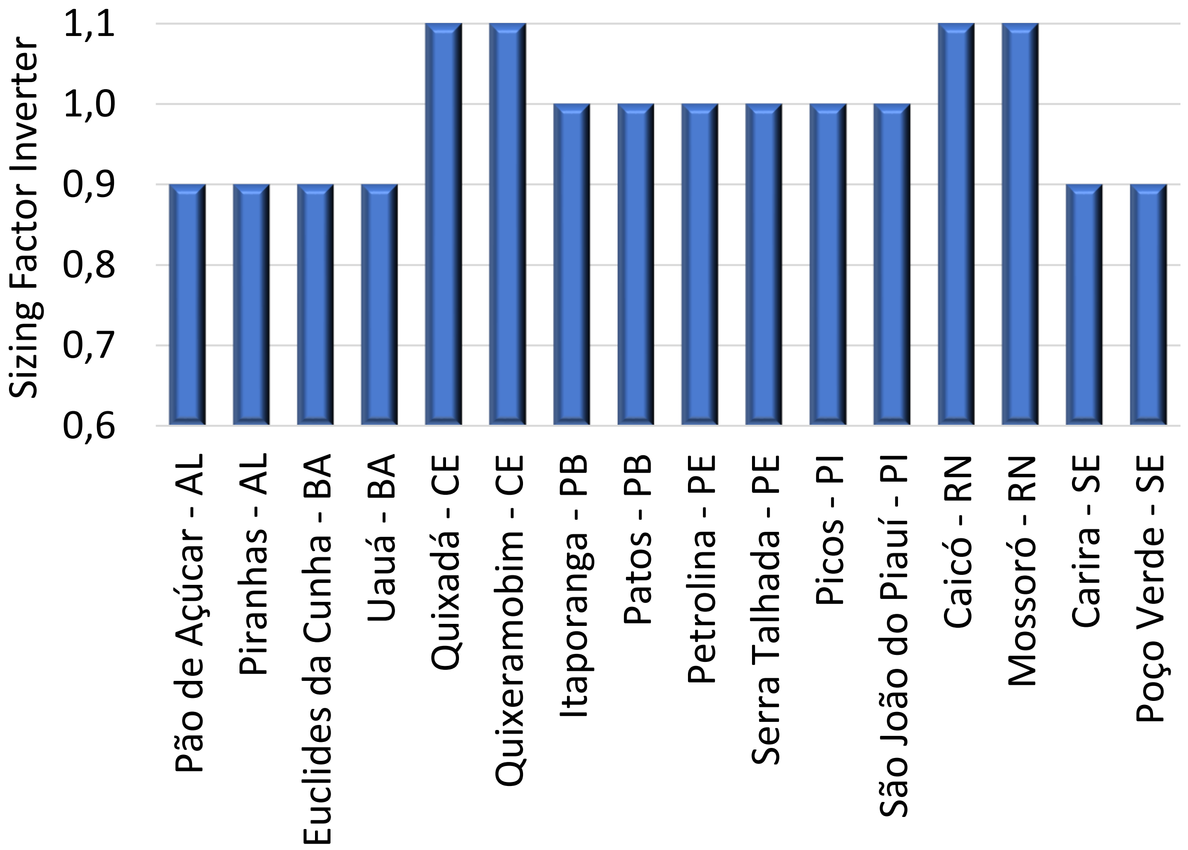
Annual productivity, using (3) to calculate T_c



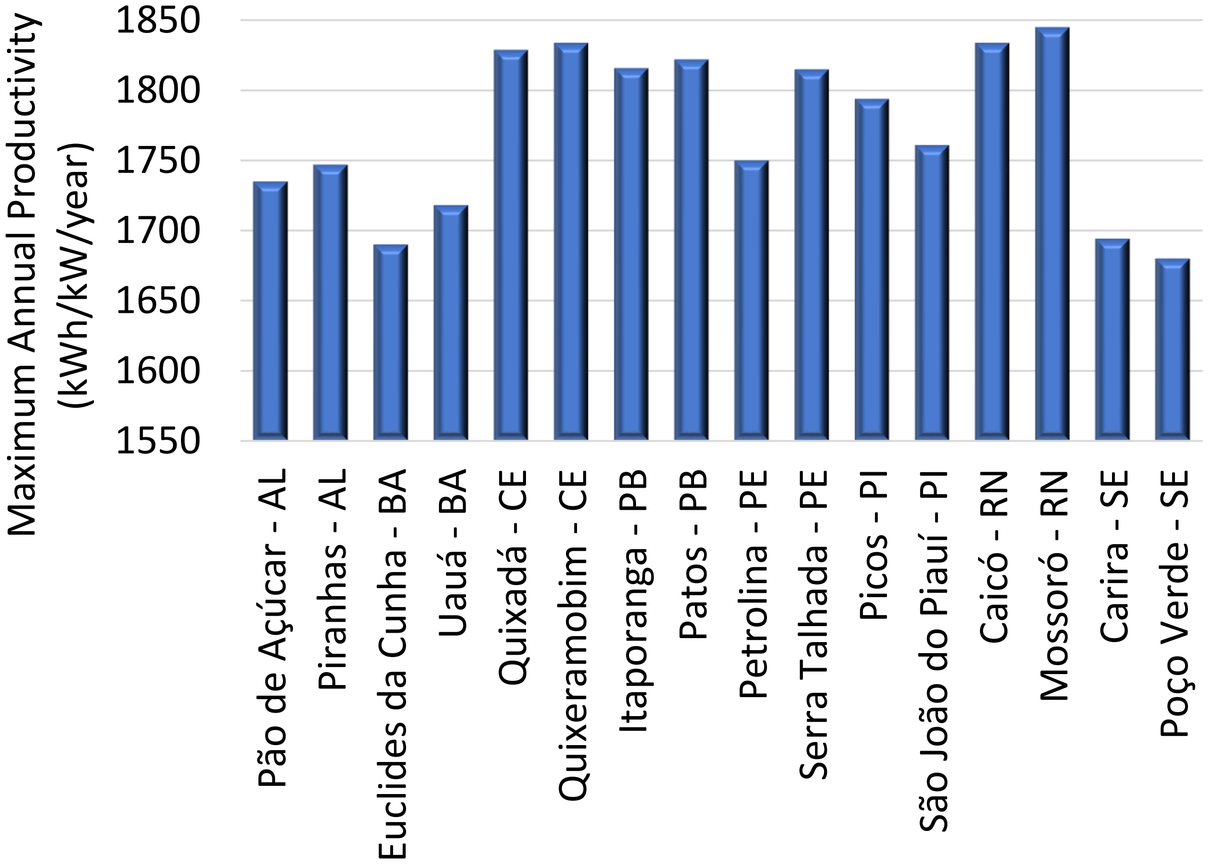
Annual productivity, using (2) to calculate T_c

SIMULATION RESULTS

✓ Annual Productivity:



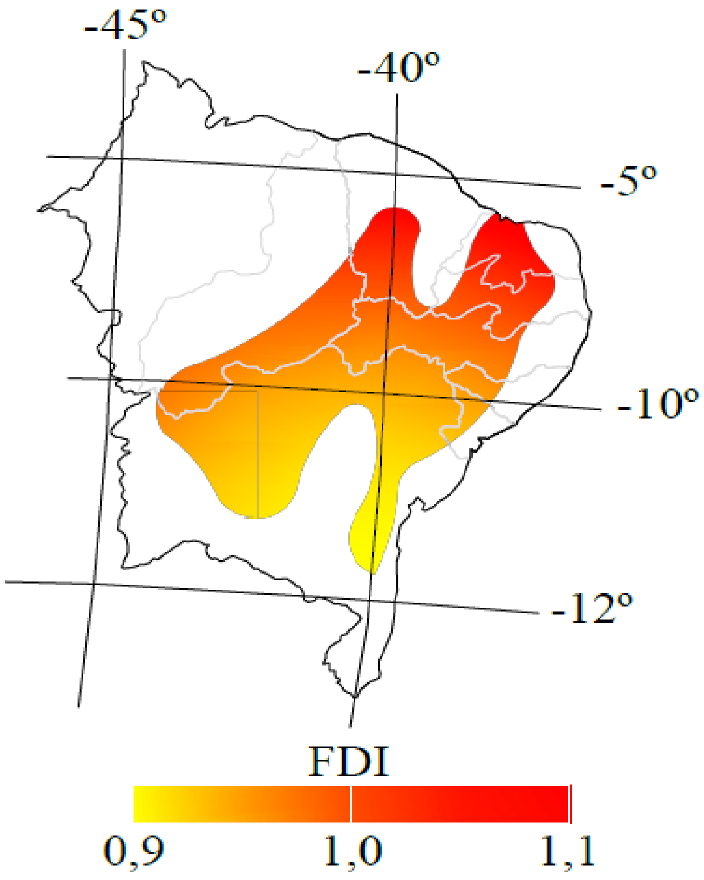
SFI that results in maximum annual productivity of grid-connected PV systems, by city



Annual productivity of grid-connected PV systems, by city

SIMULATION RESULTS

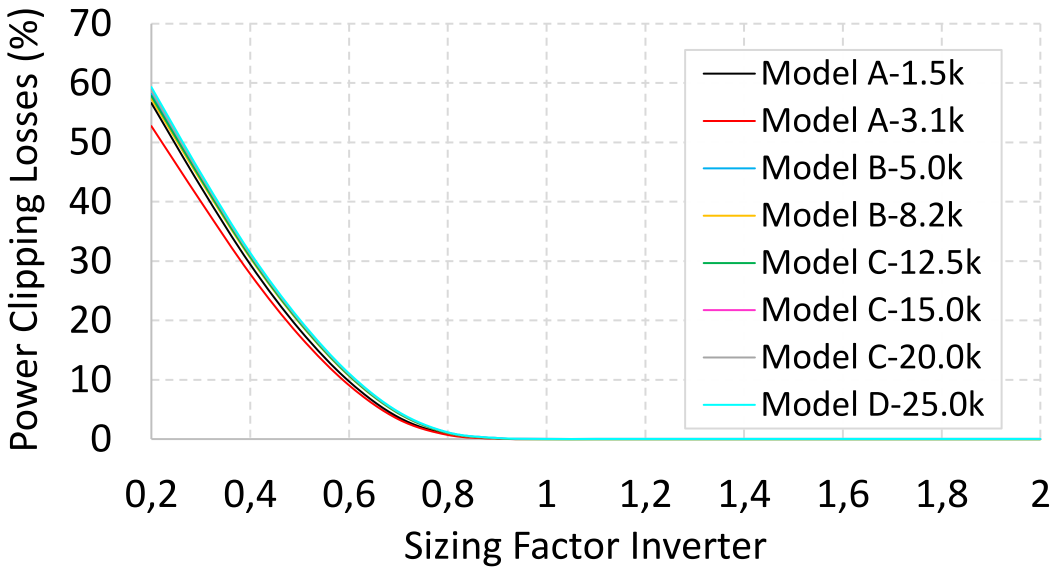
- ✓ Annual Productivity:



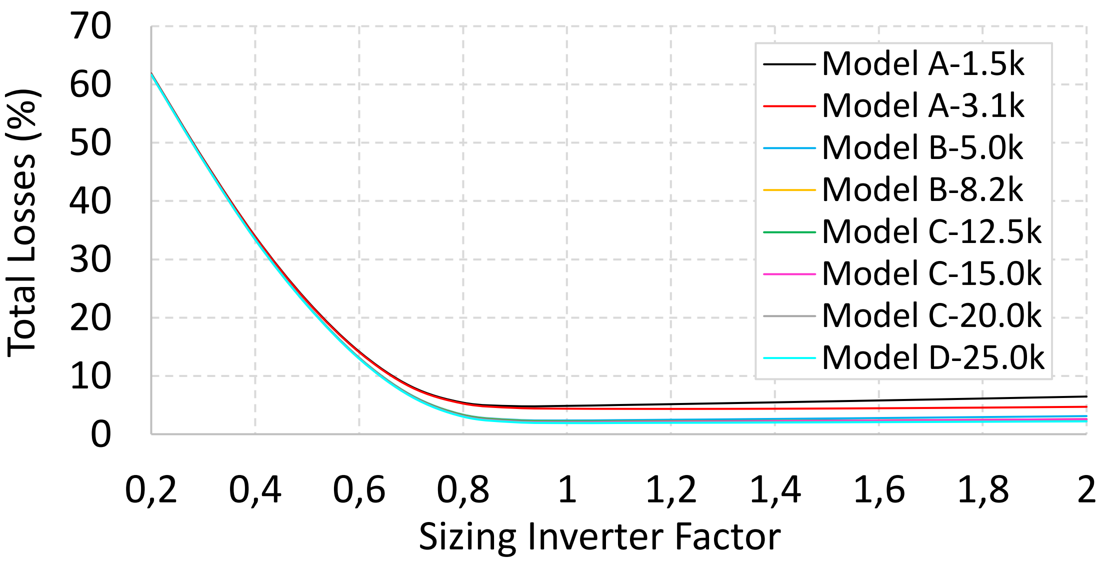
Map of SFI values that results in greater productivity indices in semiarid tropical climate area in Northeast Brazil

SIMULATION RESULTS

✓ Inverter Losses:



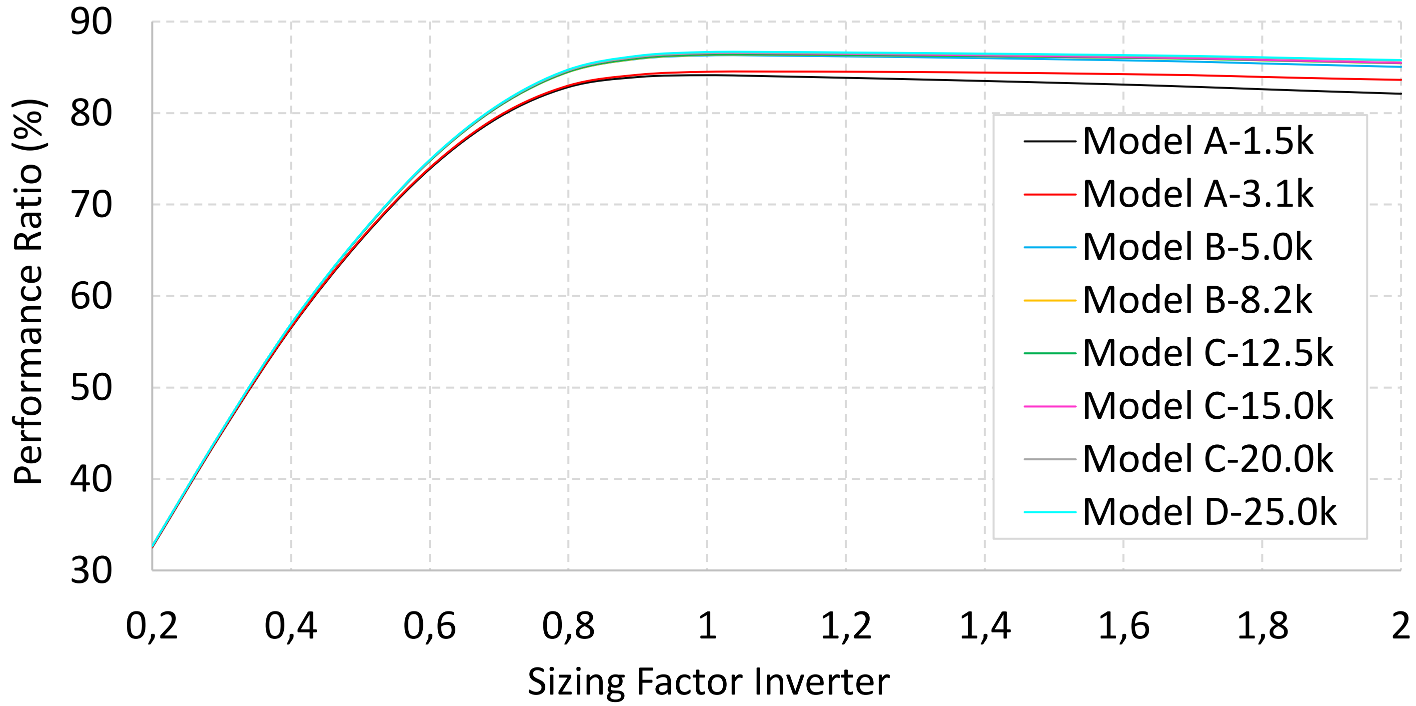
Inverter power clipping losses



Inverter total losses

SIMULATION RESULTS

✓ Performance Ratio:



Performance ratio in function of SFI

CONCLUSIONS

- ✓ Inverter efficiency, solar irradiance, ambient temperature, wind speed and relative humidity can influence the calculation of SFI and the annual productivity of grid-connected PV systems;
- ✓ PV systems installed in locations with semiarid tropical climate, SFI values equal to or greater than 0.9 and inferior to 1.1 provide higher annual average productivity;
- ✓ SFI value for more efficient inverters is greater;
- ✓ Although factors such wind speed and relative humidity influence SFI calculations, solar irradiance has more influence in determining this parameter;
- ✓ For locations with higher levels of solar irradiance, higher the SFI will be;
- ✓ SFI value tends to be higher for locations with lower latitude.

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Thank you!

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