Software for calculating the optimum tilt angle of PV modules in different latitudes of the Southern hemisphere and solar plant sizing

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1. Introduction

In Brazil, although most of the energy mix is constituted of renewable energy[1] the demand for PV systems has shown exponential leaps due to the reduction of material prices, high-energy potential and good financial return.

Therefore, through the use of an isotropic method for predicting the radiation upon a solar-energy collector for the calculation of the optimum tilt angle of installation, the calculation for the inter-row spacing of PV arrays, and use of Particle Swarm Optimization in order to cut processing time, this paper presents a software that can be used in the PV system software market.

2. Photovoltaic Modules

The software is configured to use landscape-oriented PV modules for the system optimization and the dimensions of the chosen model are 2108 X 1048 X 40 mm[2].

3. Sun Trajectory and the irradiation on a terrestrial surface

In order to have a higher power generation the modules are installed at a certain angle that receives the highest amount of average solar irradiation throughout the year.

The installation angle vary for several factors, the main ones being the latitude and hemisphere. For this, the trajectory of the sun and the irradiation during the days of the year are mathematically modeled in relation to a flat surface installed on the Earth.

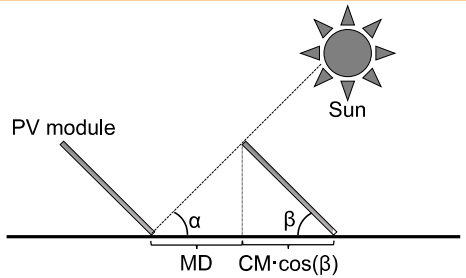
$$It. = Idir. \cdot Rdir. + Idif. \cdot \left(\frac{1+\cos\beta}{2}\right) + Ialb. \cdot 0{,}2 \cdot \left(\frac{1-cos\beta}{2}\right) \quad (1)$$

4. Particle swarm optimization for the maximization of the Solar Mean irradiation

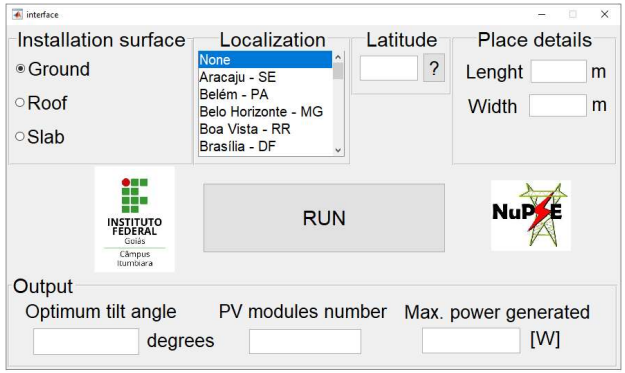
For each installation angle an analysis is made for 365 days of the year, totaling approximately 32 million analyzes performed by the user's computer for only one latitude value.

Problems with large amounts of variables can be solved by metaheuristic methods such as the Particle Swarm Optimization (PSO). In the last iteration of the program reaches in the optimum tilt angle that maximizes the mean solar irradiation using the Liu and Jordan isotropic method.

5. Shading effect

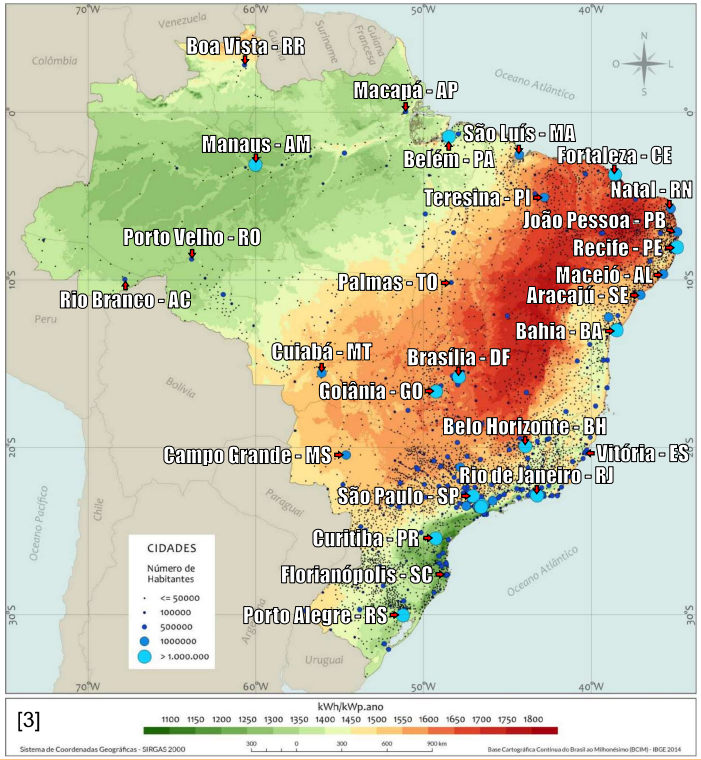


6. Software Interface



7. Results

City	Latitude (°)	Liu and Jordan: Optimum tilt angle (°)	Liu and Jordan: Solar radiation (kWh)
Aracaju - SE	-10,9162	8,4752	3,0463
Belém - PA	-1,4500	1,2080	3,0323
Belo Horizonte - MG	-19,9185	15,5504	3,0861
Boa Vista - RR	2,8208	1,7926	3,0340
Brasília - DF	-15,7935	12,2914	3,0652
Campo Grande - MS	-20,4666	15,9942	3,0881
Cuiabá - MT	-15,5987	12,1297	3,0498
Curitiba - PR	-25,4306	20,0336	3,1290
Florianópolis - SC	-27,5973	21,8149	3,1489
Fortaleza - CE	-3,7668	2,9826	3,0333
Goiânia - GO	-16,6805	12,9759	3,0630
João Pessoa - PB	-7,1282	5,5547	3,0322
Macapá - AP	0,0402	0,0000	3,0326
Maceió - AL	-9,6522	7,4963	3,0394
Manaus - AM	-3,1330	2,4945	3,0324
Natal - RN	-5,8104	4,5435	3,0354
Palmas - TO	-10,1866	7,9140	3,0359
Porto Alegre - RS	-30,0346	23,8832	3,1742
Porto Velho - RO	-8,7495	6,8025	3,0290
Recife - PE	-8,0729	6,2827	3,0375
Rio Branco - AC	-9,9739	7,7427	3,0285
Rio de Janeiro - RJ	-22,9068	17,9727	3,0985
Salvador - BA	-12,9858	10,0792	3,0535
São Luís - MA	-2,5635	2,0585	3,0326
São Paulo - SP	-23,5487	18,4763	3,1080
Teresina - PI	-5,0896	3,9917	3,0344
Vitória - ES	-20,3201	15,8768	3,0901



[3]

8. Conclusion

The developed software returns through the latitude angle and site characteristics, the value of the best angle of photovoltaic modules using the Liu and Jordan method, the number of modules and the maximum generation.

Regarding the values of angle and solar irradiation, it is demonstrated that there is no need for great accuracy (four decimal digits) in the installation, because the difference in radiation, and consequently, generation will not be large in the long-term. Furthermore, it is concluded that the prediction of the best installation angle is an approximation and a study should be done for each location taking into account variables such as weather and number of cloudy days.

References

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