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The Uses of Lorentzian Peak Function for Solar Energy Projection at Badung Regency, Bali Province

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Abstract. This research aims to prepare daily solar energy data for the government and the community in Badung Regency, Bali Province. This study uses primary data from Lutron SPM-1116SD solar power meter at two locations, i.e., Buduk Village, Mengwi District, and Bongkasa Pertiwi Village, Abiansemal District. These two locations are in Badung Regency, Bali Province. We collected the primary data collection from September 2020 to March 2021 when the sun moved from the equator to

the December equinox and returned to the equator. First, we put both solar power meters on the flat horizontal surface. Then, the primary data from both solar power meters are selected every month and processed to obtain the solar energy value. Next, we perform data fitting with the Lorentzian Peak Function (LPF) and calculate the solar energy value. After that, we compare the solar energy value of the LPF with the primary data value using the statistics of Two-Samples of Kolmogorov-Smirnov. At the 0.05 level, there is no significant difference between the solar energy data value compared with the solar energy LPF fitting value. Thus the LPF can project the solar energy value from September to March at Badung Regency, Bali Province. INTRODUCTION Research on solar energy is essential to support the application of new and renewable energy in a location. Sibagariang et al. conducted a study on the Potential of Solar Energy on Medan, City of Indonesia: Comparison of Clear Sky, Satellite, and Field Measurements [1]. Syanalia and Winata stated that Bali has a stable and long sunny day with 12 hours of daylight throughout the year and average insolation of 5.3 kWh/m2 per day [2]. Winarso stated that Indonesia's maritime continents categorize as a good area with annual average solar irradiance between 1000–1600 KW hour/meter square [3]. Sugirianta et al. noted that the simulations found that for fixed solar panels in a year, the optimum tilt angle values are from 12 to 18 degrees in the azimuth of 0-degree direction with the system output at 528 kWh/year [4]. Fathoni et al. found that the proposed system can generate electricity annually from 0.46 GWh/year in Denpasar to 217 GWh/year in Pontianak [5]. Our research group has also published an article about monthly clear sky solar irradiation in Denpasar City from April to October, focusing on the effect of the June Solstice [6]. Several researchers have also researched the Lorentzian Peak Fu nction (LPF) application. Abdellatif et al. have researched Modeling Various Solar Cells Materials Using Lorentzian-Drude Coefficients [7]. Becker et al. prepared Polycrystalline silicon (poly-Si) thin films by electron-beam evaporation and thermal annealing for the development Proceeding of International Conference on Energy, Manufacture, Advanced Material and Mechatronics 2021 AIP Conf. Proc. 2630, 020007-1–020007-6; https://doi.org/10.1063/5.0126171 Published by AIP

of thin-film solar cells on glass coated with ZnO:Al as a transparent, conductive layer. A Lorentzian peak around 520 cm−1 corresponds to crystalline silicon's transverse optical (TO) phonon [8]. Zubkins et al. studied structure and conduction type changes upon adding Ir to ZnO thin films where LPF was used to obtain the position (frequency of the mode) and full-width at half-maximum (FWHM) of the peak [9]. Kment et al. estimated the data of X-ray photoelectron spectroscopy from the binding energy lines of photoelectrons of the internal valence core of oxygen (O 1s) and nitrogen (N 1s) and their intensities by fitting the experimentally obtained spectra (mixed Gaussian and LPF) [10]. In this article, we report the uses of LPF for solar energy projection at Badung Regency, Bali Province. RESEARCH METHODOLOGY We collected the solar power data at Buduk Village, Mengwi District (location at -8.608607, 115.160006) and Bongkasa Pertiwi Village, Abiansemal District (site at -8.469633, 115.238608). Both sites are at Badung Regency, Bali Province, Indonesia, separated by 17.62 km. Solar power data was collected from September 2020 to March 2021 on a horizontal surface using SPM-1116SD. The sun moves from the equator towards the December equinox and back to the equator in those months. Figure 1 shows primary data collection regarding solar power in Buduk Village. Primary data is then processed to obtain insolation data in units of Watt-hour per square meter. The data from both solar power meters are then selected every month and processed to obtain the solar energy value and fitted using the Lorentzian Peak Function. After that, we calculate the solar energy value. The last, using the statistics of the Two Samples Kolmogorov-Smirnov test, we compare it by the primary data of solar energy value. Furthermore, we determine the value of the Lorentzian Peak Function parameters to project the solar energy value from September to March in Badung Regency, Bali Province, Indonesia.   FIGURE 1. SPM-1116SD at Buduk Village. The Lorentzian Peak

Function equation used is under Equation (1). $y \quad y \quad 2A \, \pi$

$w \; 4 \quad x \quad x \quad w$ 1 With parameters y ,

x ,w, and A are the offset, center, width, and area, respectively. RESULT AND DISCUSSION Solar Power Data at Badung Regency We provide the solar power data from September 2020 to March 2021 at Buduk Village, Mengwi District, and Bongkasa Pertiwi Village, Abiansemal District. The data is selected on the best weather conditions to get the highest daily solar power data information for each month. Figure 2 shows primary data regarding solar power selected from both locations. 020007-2

(a) (b) (c) (d) (e) (f) (g) FIGURE 2. Solar power data on (a) September 2020, (b) October 2020, (c) November 2020, (d) December 2020, (e) January 2021, (f) February 2021, (g) March 2021 Figure 2 shows that in September 2020, when the sun was at the equator, the maximum value of solar power was 1289 W/m2 on September 18, 2020, in Buduk Village. Furthermore, when the sun goes to the northern equinox, the maximum value of solar power is obtained at 1356 W/m2 on October 14, 2020, in Bongkasa Pertiwi Village. In the following month, on November 8, 2020, the maximum value of solar power was 1110 W/m2 in Buduk Village. When the sun approached the December equinox, the top solar power value of 1028 W/m2 was in Buduk Village on December 26, 2020. Furthermore, when the sun led from the December equinox to the equator on January 21, 2021, on this date, the maximum value of solar power was 1175 W/m2 in Bongkasa Pertiwi Village. In the following month, on February 7, 2021, the ultimate value of solar power was 1123 W/m2 in Buduk Village. Finally, when the sun approached the equator on March 27, 2021, the maximum value of solar power was 1278 W/m2 in Bongkasa Pertiwi Village. Solar Power Energy Analysis Based on the primary solar power data shown in Figure 3, we carried out the Lorentzian Peak Function (LPF) fitting. We display the results of LPF fitting in Figure 3 and the LPF parameters in Table 1.

All the LPF fittings from

September 2020 to March 2021 are declared fit converged with a Chi-square tolerance value of 10-9, except in October 2020 due to the high rainfall in this month at both data collection locations. (a) (b) (c) (d) (e) (f) (g) FIGURE 3. Solar power primary data and LPF fitting on (a) September 2020, (b) October 2020, (c) November 2020, (d) December 2020, (e) January 2021, (f) February 2021, (g) March 2021 Furthermore, we calculate solar energy from September 2020 to March 2021 based on daily solar power primary data and LPF fitting results displayed in Figure 3 by integrating with time. Therefore, we express both integration results in Table 2.

TABLE 1. Parameters of LPF fitting from September to March. Month Parameters Value Standard Error September y0 -734.48532 35.23838 xc 378.17482 0.77258 w 574.92142 11.86437 A 1.67166×10^6 62963.55826 October y0 -13180.90114 33247.24219 x c 390.77765 3.78263 w 3113.54048 3926.39817 A 6.7805×10^7 2.48055×10^8 November y0 -922.13565 48.5905 x c 396.53826 0.81223 w 683.98936 16.06742 A 2.14542×10^6 98792.56865 December y 0 -827.2217 71.62081 x c 399.37141 1.32008 w 709.63694 27.43617 A 1.95442×10^6 149958.3683 January y0 -215.58642 17.63548 x c 389.49728 1.26259 w 372.28469 9.85575 A 650515.45023 24419.54811 February y0 -738.85723 25.29757 x c 384.62182 0.55516 w 601.5783 8.98845 A 1.69035×10^6 46827.40601 March y0 -1211.09443 223.55227 x c 372.60929 2.36467 w 798.83606 70.66518 A 2.63324×10^6 501963.78383 TABLE 2. Solar energy data and LPF fitting from September 2020 to March 2021. Month Solar Energy of Primary Data (W-h/m2) Solar Energy of LPF Fitting (W-h/m2) September 7077.968 7078.814 October 5267.473 5269.276 November 7379.912 7380.794 December 6504.770 6505.492 January 4966.527 4966.617 February

5880.417 5881.619 March 5927.282 5928.812 Furthermore, using the descriptive statistics shown in Table 3 and the Two-Sample Kolmogorov-Smirnov Test, the results obtained are D value 0.14286 and Z = 0.26726 with the conclusion at 0.05 level, solar energy of primary data and solar energy of LPF fitting are not significantly different. Therefore, although in October it appears that there is a difference in the solar power data graph with the LPF fitting in Figure 3b, the calculation results for solar energy LPF fitting show the same results as the primary data solar energy. Hence, to project daily solar energy from September to March in Badung Regency, Bali Province, one can use LPF as s hown in Equation (1) and enter parameters value according to Table 1. 020007-5

TABLE 3. Descriptive statistics of solar energy data and LPF fitting from September 2020 to March 2021. Month N 5 Min Q1 Median Q3 Max Primary Data 7 4966.527 5267.473 5927.282 7077.968 7379.912 LPF Fitting 7 4966.617 5269.276 5928.812 7078.814 7380.794 CONCLUSION This article presents data on solar energy in Badung Regency, Bali Province, from September 2020 to March 2021. It is analyzed using the LPF equation and shows the same results as primary data. At 0.05 level, solar energy of primary data and solar energy of LPF fitting are not significantly different. Due to the sun's apparent movement, which seems to move from south to north and back to the south from day to day every year, then the LPF with parameters shown in Table 1 can project daily solar energy from September to March in Badung Regency, Bali

Province. ACKNOWLEDGMENTS We thank the IC-EMAMM 2021 committee for editing and reviewing the article and publishing it in the AIP Conference Proceeding. We also thank the village officials at the location of data collection. REFERENCES 1. Y. P. Sibagariang, H. V Sihombing, and E. Y. Setyawan, “The 1 potency of solar energy on Medan city of Indonesia: Comparison of clear sky, satellite and field measurements,” AIP Conf. Proc. 2221, vol. 070002, March, 2020. 2. A. Syanalia and F. Winata, “Decarbonizing

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