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Original Research Article

# Greenough River Solar Farm case study & validation initialization



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## ABSTRACT

Large Photovoltaic Solar Power Plants (LPVPPs) and Very Large Photovoltaic Solar Power Plants (VLPVPPs) may have rapid success in the revolutionary change of the national and international power grids to build a 100% renewable power Global Grid. The Australian continent has outstanding solar resource availability, enabling widespread utilization of solar power and power storage technologies (e.g. pumped hydroelectric, thermal, electrochemical). Design and investment modeling of the renewable power grid is the success key for a 100% renewable power grid. The design and investment in LPVPPs and VLPVPPs should preferably be undertaken with the consideration of values such as environmental friendliness, fairness, openness to small private investors, reliability, and accountability. The design of LPVPPs and VLPVPPs should preferably be based on some small-scale PV power plants to help reduce the risks for large to very large investments. Hence, validation and verification efforts of operational PV power plants with different design software are very important for the solar industry. This research paper presents the first specific validation and verification study of the Greenough River Solar Farm (12,68 $MW_{DC}$, 10,00 $MW_{AC}$, the first planned expansion to 40,00 $MW_{AC}$ in 2019) near Geraldton in Western Australia with the PVWatts Version 5 model of the National Renewable Energy Laboratory (NREL) System Advisor Model (SAM) Version 2017.9.5. The National Aeronautics and Space Administration (NASA) Modern-Era Retrospective Analysis for Research and Applications Version 2 (MERRA-2) datasets are used as a weather data source in this study. Location and resource, system design data and information on the Greenough River Solar Farm in this study are presumptions based upon publicly available information without any confirmation of power plant owners and operators. The Greenough River Solar Farm NREL SAM software models' are run on 2 different personal computers (PCs) with internet connection for years 2013 to 2017. The results of 6 simple simulations are compared with actual generation data for 2013 through 2017 with some statistical performance measures of the global unique forecast accuracy metrics pool in the Global Grid Prediction Systems ($G^2PS$). The simulations average total time (milliseconds) are 64.1 and 77.9. The best model/actual accuracy measure is 101.9%. The minimum root mean square error (RMSE) is 254.142 MWh in 2013. The maximum RMSE is 414.931 MWh in 2014.

*Keywords:* SAM, System Advisor Model, Greenough River Solar Farm, Very Large Photovoltaic Solar Power Plants, NASA MERRA-2, Australia

## 1. Introduction

Large Photovoltaic Solar Power Plants (LPVPPs) and Very Large Photovoltaic Solar Power Plants (VLPVPPs) are the most feasible main items of 100% renewable power grids [1-3]. They have some major advantages such as ease of management, ease of operation and maintenance, economies of scale, and ease of design, engineering, procurement, and construction. Their private investment models will be less difficult with some new investment model approaches such as openness to small-scale investment for ordinary people, investing in small to medium-sized companies and business opportunities, that most possibly create more jobs than large-sized companies and business opportunities.

LPVPP and VLPVPP design, engineering, procurement, and construction processes are almost the same as the utility-scale photovoltaic solar power plant (PVPP) design, engineering, procurement and construction processes. PV design tools are as important as the talents and experiences of designers and engineers in this long design spiral. There are many software alternatives for modelling PV systems. For instance; FreeGreenius [4], and System Advisor Model (SAM) [5]. Their models, algorithms, user interfaces, and user data and information requirements differ greatly (PV design tools). Hence, validation and verification research efforts of these software programs and their publications are worthwhile. This research study focuses on the NREL SAM software, that has been developed and used by many organizations and researchers such as the National Renewable Energy Laboratory (NREL), the University of Wisconsin (UW) for more than 10 years (see Table 1) [5-11]. The NREL SAM PVWatts V5 model in the latest NREL SAM software release (System Advisor Model Version 2017.9.5, 64 bit, updated to revision 3 SSC Version 184: Windows 64 bit Visual C++) is used in the current study [5-11]. This is the first main validation and verification research objective and motivation of the current study and its publication.

**Table 1.** Some Important System Advisor Model (SAM) Release [5]

| Title | Date |
|---|---|
| Version 1.1 | August 2007 |
| Version 2.0 | June 2008 |
| Version 3.0 | June 2009 |
| Version 2009.10.2 | October 2009 |
| Version 2010.3.31 | March 2010 |
| Version 2011.5.4 | May 2011 |
| Version 2012.5.11 | May 2012 |
| Version 2013.9.20 | September 2013 |
| Version 2014.11.24 SSC Version 40 | November 2014 |
| Version 2015.1.30 SSC Version 41 | January 2015 |
| Version 2016.3.14 SSC Version 159 | March 2016 |
| Version 2017.1.17 SSC Version 170 | January 2017 |
| Version 2017.9.5 Revision 3, SSC Version 184 | February 21, 2018 |

There are many PV panel technology developers such as First Solar, SunPower®, Yingli Green, SolarWorld, REC Group, Trina Solar, Suntech Power, Hanwha Q CELLS, JA Solar, Canadian Solar, Jinko Solar with several PV cell technologies such as monocrystalline silicon: Mono-Si or sc-Si (e.g. SunPower® X-Series, SunPower® E-Series, SunPower® P-Series, Yingli Green Panda Bifacial 60CF), multicrystalline (e.g. YGE 60 Cell Series 2), thin film cadmium telluride: CdTe (e.g. First Solar Series 4™, First Solar Series 6™) with different cell efficiencies (i.e. 22.8%; 20.4%; 17.2%; 17.0%) in the photovoltaic solar power industry [12-22]. The PV panel technology developers' technical performances differ greatly. Hence, validation and verification research efforts of them on some software programs and their publications are worthwhile (PV panel technology developers). This research focuses on the First Solar Series 3 Black technology [12]. This is the second main validation and verification research objective and motivation of the current study and its publication.

There are many PVPPs installed with the First Solar PV panel technology. For instance, Mohammed Bin Rashid Al Maktoum Solar Park, 13 MW with 152.880 fixed tilt modules, in Dubai; Shams Maan Power Generation Solar Photovoltaic Power Plant, 52,5 MW with single axis trackers, in Jordan; Mahabugnagar Solar Park, 10 MW with 142.290 fixed tilt modules, in India; Hindupur Solar Park, 40 MW with 432.564 fixed tilt modules, in India; Otjozondjupa Solar Park, 5 MW with 52.000 single axis tracking modules, in Namibia; Topaz Solar Farm, 550 MW with 9.000.000 fixed tilt modules, in the U.S.A.; Copper Mountain Solar 1, 58 MW with 1.000.000 fixed tilt modules, in the U.S.A.; Agua Caliente Solar Project, 290 MW with 5.200.000 fixed tilt modules, in the U.S.A.; Luz del Norte, 141 MW with 1.700.000 fixed tilt modules, in Chile; Wellington Solar Farm, 180 MW with 511.630 single axis tracking modules, in New South Wales on the east coast of Australia; Greenough River Solar Farm, 10 MW with 152.000 fixed tilt modules, in Western Australia on the west coast of Australia [12]. The PVPPs' technical performances differ greatly in different regions of the World. Hence, validation and verification research efforts of them on some software programs and their publications are worthwhile (PVPPs). This research focuses on the Greenough River Solar Farm with 152.000 fixed tilt First Solar Series 3 Black modules [12, 23] in the south west of Western Australia. This solar farm has been included as one aspect of the previous publications regarding the potential for renewable energy in the south west of Western Australia [24, 25]. This is the third main validation and verification research objective and motivation of the current study and its publication.

There is an expansion plan of the Greenough River Solar Farm from 10 $MW_{AC}$ to 40 $MW_{AC}$. The investment risks can be minimized with some meticulous research studies in every aspect of the Greenough River Solar Farm with its current 10 $MW_{AC}$ capacity. Moreover, the authors have an ongoing research study to design a VLPVPP in the same location of the Greenough River Solar Farm as its expansion to thousands of megawatts (e.g. 1000 $MW_{AC}$, 2000 $MW_{AC}$). The minimization of costs and risks and the maximization of electricity generation in this VLPVPP are crucial (start investing with 10 $MW_{AC}$ and expand investing to 1000 $MW_{AC}$, 2000 $MW_{AC}$ and so on). This is the fourth main validation and verification research objective and motivation of the current study and its publication.

In conclusion, as it might shortly be presented at the end of this section, there are 7 major validation and verification research objectives, motivations, and contributions of this study and its paper. These objectives, motivations, and contributions are basically its representation capability of a validation and verification effort for the PVWatts V5 model on the NREL SAM Version 2017.9.5 Revision 2, SSC Version 180, its representation capability of the First Solar Series 3 Black technology with a fixed tilt application in the south west of Western Australia (Greenough River Solar Farm), its contribution to the research and development efforts of VLPVPPs on a global scale, its contribution to the research and development efforts of the Global Grid Prediction Systems ($G^2PS$), the Global Grid Electricity Demand Prediction System ($G^2EDPS$), and the Global Grid Peak Power Prediction System ($G^2P^3S$), the Global Grid Generation Side Prediction Systems ($G^3SPS$), the Global Grid Generation Side Electricity Generation Prediction System ($G^3SEGPS$), the Global Grid Generation Side Peak Power Prediction System ($G^3SP^3S$), the Global Grid Generation Side Cost Prediction System ($G^3SCPS$), the Global Grid Consumption Side Prediction Systems ($G^2CSPS$), the Global Grid Consumption Side Electricity Demand Prediction System ($G^2CSEDPS$), the Global Grid Consumption Side Peak Power Prediction System ($G^2CSP^3S$), the Global Grid Consumption Side Price Prediction System ($G^2CSP^2S$) [26–29], and finally its contribution to the research efforts on climate change.

## 2. Greenough River Solar Farm

The Greenough River Solar Farm is a joint venture business model between Synergy and GE Energy Financial Services (General Electric). The Greenough River Solar Farm was constructed between April 2012 and July 2012. The first First Solar's CdTe thin-film PV modules were installed on 12 April 2012. The installation of all panels was finalized in July 2012. The commissioning of the Greenough River Solar Farm took one month (late July 2012 to late August 2012). It was officially opened in October 2012 [23].

### 2.1. Location

Greenough River Solar Farm (10,00 MW, Planned Expansion: 40,00 MW) on Google Earth Pro 7.1.5.1557 [30] are as follows (open Greenough River Solar Farm.kmz) (Figure 1):

Latitude & Longitude: 28°54'22.71"S, 115° 6'54.59"E; 28°54'6.38"S, 115° 6'54.80"E; 28°54'6.14"S, 115° 6'28.51"E; 28°54'11.90"S, 115° 6'28.47"E; 28°54'11.92"S, 115° 6'30.42"E; 28°54'22.25"S, 115° 6'30.49"E.

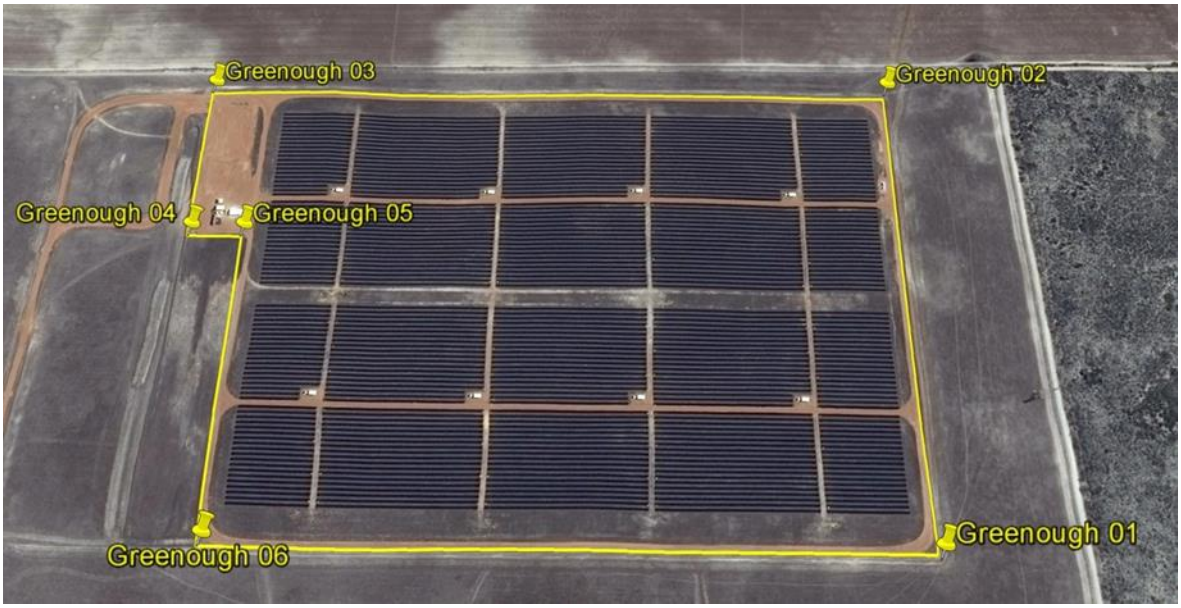



**Figure 1.** Greenough River Solar Farm location (10,00 $MW_{AC}$, 12,68 $MW_{DC}$, Planned expansion: 40,00 MW) in yellow color, (according to the literature review) (generated by Google Earth Pro 7.1.5.1557 [30], Paint.NET.4.0.16 [31]).

### 2.2. Weather file resource (Model)

The NREL SAM requires a weather data file to describe the renewable energy resource and weather conditions at a project location. The weather files used in this analysis have been derived from the National Aeronautics and Space Administration (NASA) Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) datasets [32]. These datasets potentially provide a suitable source of worldwide weather data for the NREL SAM, especially for those countries, that do not have a more accurate source of weather data.

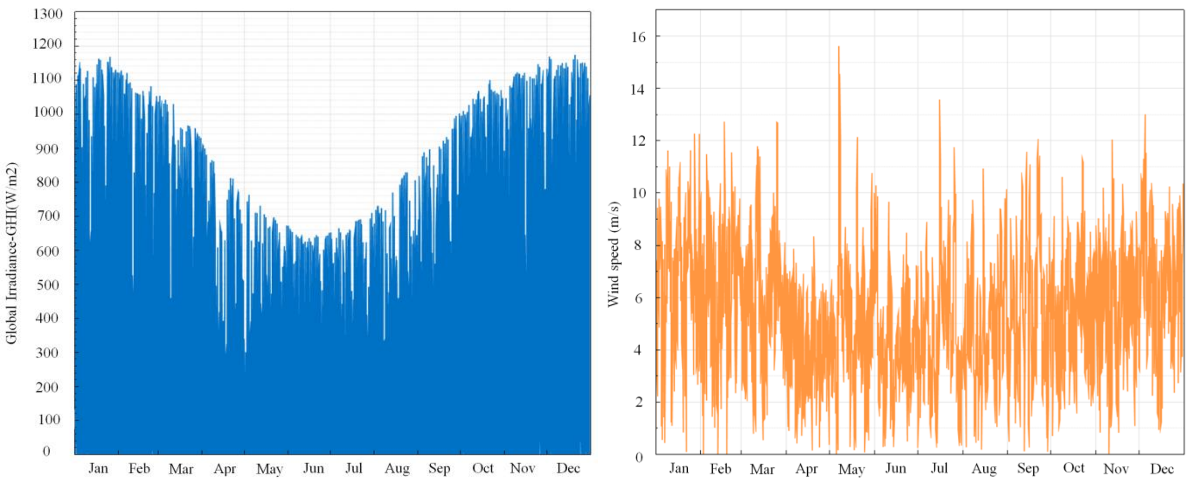
The NASA MERRA-2 provides data beginning in 1980 with worldwide coverage. The datasets provide a spatial resolution of about 55 kilometers in latitude (0.5 degree of latitude x 0.625 degree of longitude) [32]. The datasets provide a potential source for weather data covering the earth from 85 degrees north to 85 degrees south [32].

The NREL SAM weather files contain data for a full year (8.760 hours; excluding 29 February). The NASA MERRA-2 datasets are daily, requiring files for a full year to be downloaded. A Python program, getmerra2.py, has been created to simplify downloading the NASA MERRA-2 files. The program is available for download in either source format, or in a package suitable for execution under Windows [33]. Two time averaged two-dimensional NASA MERRA-2 datasets – tavg1_2d_slv_Nx Single Level Diagnostics and tavg1_2d_rad_Nx Radiation Diagnostics provide hourly data, that can be used to create NREL SAM weather files [34]. The tavg1_2d_slv_Nx dataset provides hourly temperature and pressure data (also wind data at 50 meter height, which makes it suitable for input to the NREL SAM wind model). The tavg1_2d_rad_Nx dataset provides surface incoming shortwave flux (SWGDN variable) which can be used as a proxy for the Global Horizontal Insolation (GHI) [35,36]. Using routines from the NREL, it is possible to calculate the Direct Normal Insolation (DNI) [37] and the Direct Horizontal Insolation (DHI) [38] from the GHI. This enables solar weather files to be created for input into the various NREL SAM solar models, specifically pvwattsv5. A Python program, makeweatherfiles.py, has been created to enable the NREL SAM weather files to be created from downloaded the NASA MERRA-2 files. It is available for download in the same way as getmerra2.py.

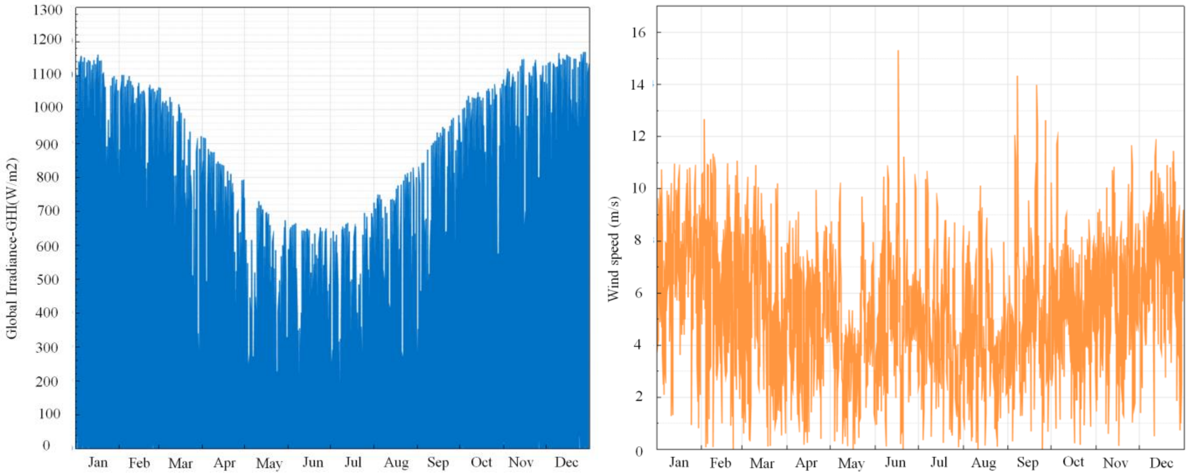
The area of the appropriate NASA MERRA-2 cell of the Greenough River Solar Farm is presented in Figure 2. The weather file information is presented on the NREL SAM Version 2017.9.5 as shown in Figure 3 (solar_weather_-29.0000_115.0000_2013.smw: 2013, solar_weather_-29.0000_115.0000_2014.smw: 2014, solar_weather_-29.0000_115.0000_2015.smw: 2015, solar_weather_-29.0000_115.0000_2016.smw: 2016, solar_weather_-29.0000_115.0000_2017.smw: 2017).


**Figure 2.** The area of the appropriate NASA MERRA-2 cell for the solar farm and the other solar farm's location within the cell. The cell is approximately 55 kilometers by 60 kilometers (generated by Google Earth Pro 7.1.5.1557 [30]).

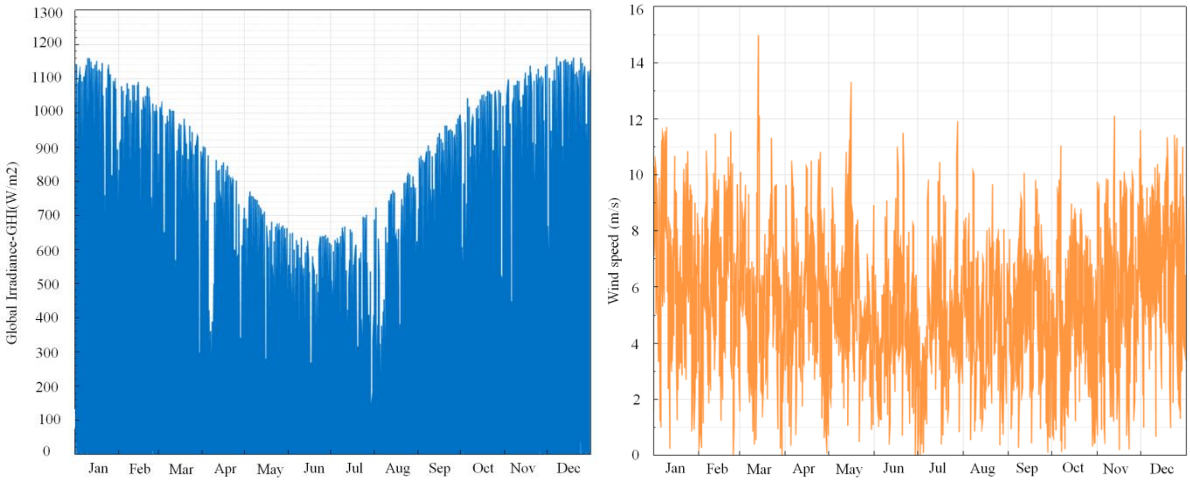
**2013**



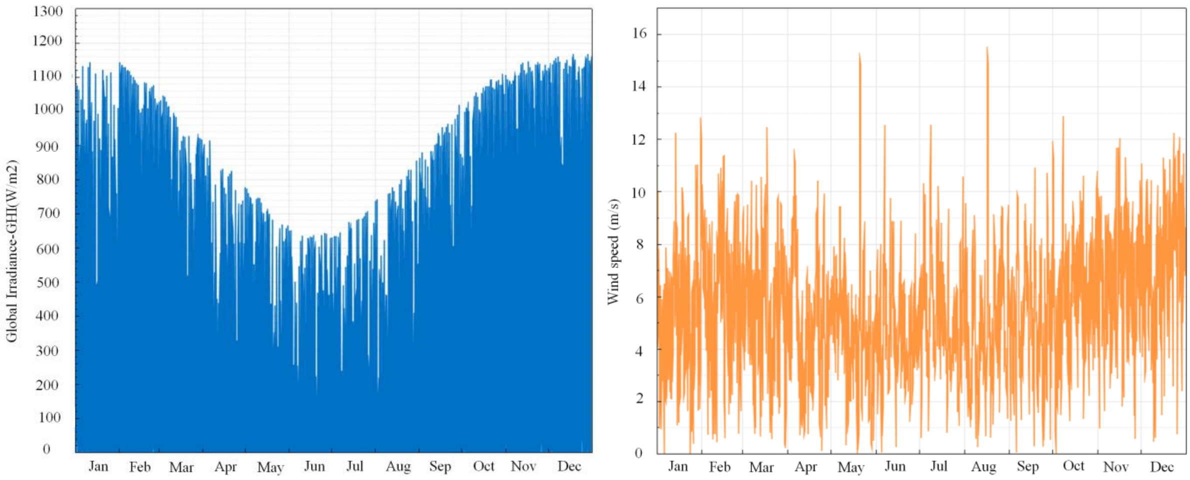
**2014**




**2015**




**2016**



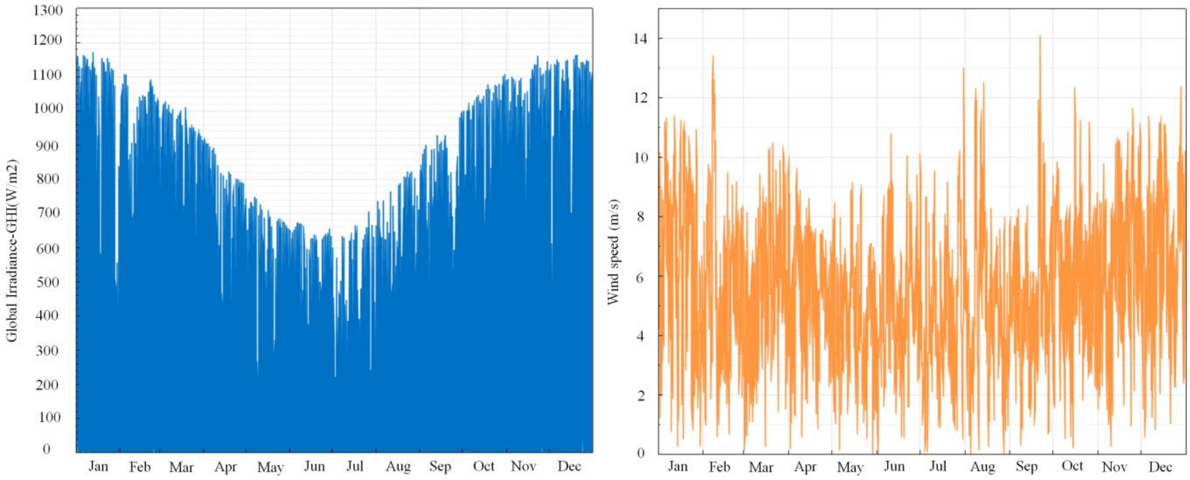



**Figure 3.** The NASA MERRA-2 Greenough River Solar Farm 2013-2017 global irradiance-GHI (W/m$^2$) (left), wind velocity (m/s) (right).

### 2.3. System parameters

The direct current (DC) capacity of the Greenough River Solar Farm is 12,68 $MW_{DC}$ [39]. Its alternating current (AC) capacity is 10,00 $MW_{AC}$ [12]. Therefore, the DC:AC ratio is calculated as 1.268. There are total 152.000 installed First Solar Series 3 PV modules (panels) with a ground coverage of approximately 80 hectares (0.8 km$^2$) [12, 39] (Table 2). The exact total number of panels cannot be found in any data and information sources, but it should be nearly 152.000 (e.g. 152.800, 152.000, 150.000) [12, 23, 39]. The FS Series 3 thin-film PV modules with cadmium telluride (CdTe) semiconductors have 5 different models with different panel efficiencies (FS-382: 11.50%, FS-385: 11.80%, FS-387: 12.20%, FS-390: 12.50%, FS-392: 12.80%) [40]. The FS Series 3 thin-film PV modules were introduced to the market in late 2013 [41]. There are SMA Sunny Central 720CP central inverters at the Greenough River Solar Farm [42, 43]. The SMA 720 kW central inverter efficiencies are found as 98.60%; 98.40%; 98.00% for the maximum efficiency, the European weighted efficiency and the CEC efficiency in the catalog of the SMA Sunny Central 720CP-US [44]. The inverters have been de-rated to 648 kW for system management reasons by giving an efficiency value of 90%. The model on the PVWatts V5, NREL SAM Version 2017.9.5 Revision 2 and actual system parameters are given in Table 2 and Table 3. As a consequence, there is a model on the PVWatts V5, NREL SAM Version 2017.9.5 Revision 2 and actual (real life) observation major mismatch in this section, due to the system configuration and the equipment properties.

**Table 2.** System Parameters of the Greenough River Solar Farm

| SAM Model Parameters | SAM Model Value | SAM Model Unit | Actual | Core References |
|---|---|---|---|---|
| System nameplate size | 12.680 | kWdc | 12.68 $MW_{DC}$ | [Craig Carter, personal communication] |
| Module type | Thin film | - | FS Series 3 thin-film PV modules | [12, 39] |
| DC to AC ratio | [a]1.268 | - | - | |
| Inverter efficiency | [b]90% | - | SMA Sunny Central 720CP and System management | [42, 43] |

[a]DC to AC ratio: *Case According To Personal Communication is 1.223, others are 1.268;* [b]*Inverter efficiency: The SMA 720 kW central inverters' efficiencies are found as 98.60%; 98.40%; 98.00% for the maximum efficiency, the European weighted efficiency and the CEC efficiency in the catalog of the SMA Sunny Central 720CP-US [44]. For system management reasons the inverters have been de-rated to 648 kW, giving an efficiency value of 90%.*

**Table 3.** Module type

| SAM Module Type | SAM Approximate Nominal Efficiency | SAM Module Cover | SAM Temperature Coefficient of Power |
|---|---|---|---|
| Standard (crystalline Silicon) | 15% | Glass | -0.47 %/°C |
| Premium (crystalline Silicon) | 19% | Anti-reflective | -0.35 %/°C |
| [a,b]Thin film | 10% | Glass | -0.20 %/°C |

[a]Thin-film: "*The thin film option assumes a low efficiency (~11 %), and a significantly lower temperature coefficient, which is representative of most installed thin film modules as of 2013. It is important to note that less common thin film module technologies may have quite different temperature coefficients than the default."* [11]. [b]FS Series 3 thin-film PV module efficiency: 11.5%-12.8% [40].

### 2.4. Orientation

The Greenough River Solar Farm in its current capacity and system configuration is a ground mount fixed tilt facility [12, 43]. Due to the strong winds experienced in the area a lower than the normal tilt angle of 20 degrees is chosen for the installation (personal communication).

Some important design elements on the PVWatts V5, NREL SAM Version 2017.9.5 Revision 2 about the orientation are as follows:

- "The array's tilt angle in degrees from horizontal, where zero degrees is horizontal, and 90 degrees is vertical and facing the equator (in both the southern and northern hemispheres." [45]
- "Azimuth, degrees: For systems north of the equator, a typical azimuth value would be 180 degrees. For systems south of the equator, a typical value would be 0 degrees." [45]

The model on the PVWatts V5, NREL SAM Version 2017.9.5 Revision 2 and actual (real life) system parameters are presented in Table 4. There is a high possibility of the model and actual (real life) observation major mismatch in the orientation.

**Table 4.** Orientation Parameters.

| Model Parameters | Model Value | Model Unit | Actual | References |
|---|---|---|---|---|
| Array type | Fixed open rack | - | Ground Mount Fixed Tilt | [12,43] |
| Tilt | 20° | degrees | 20° | |
| Azimuth | 0° | degrees | 0° | |

### 2.5. Losses

The system losses of the PVWatts Version 5 model of the NREL SAM Version 2017.9.5 are soiling loss, shading loss, snow loss, mismatch loss, wiring loss, connections loss, light-induced degradation loss, nameplate rating loss, age loss, and availability loss. The short explanations of these system losses are as follows:

- Soiling Loss: "due to dust, dirt, and other foreign matter on the surface of the PV module that prevent solar radiation from reaching the cells" [45]
- Shading Loss: "Reduction in the incident solar radiation from shadows caused by objects near the array such as buildings or trees, or by self-shading for fixed arrays or arrays with two-axis tracking. For fixed arrays or arrays with two-axis tracking that consist of multiple rows of modules, you can use the table below to choose a loss percentage to represent self-shading (losses that occur when modules in one row cause shadows on those in an adjacent row). Industry practice is to optimize the use of space by configuring the PV system for a GCR that corresponds to a shading derate factor of 0.975 (2.5% loss)." (see Figure 4) [45]

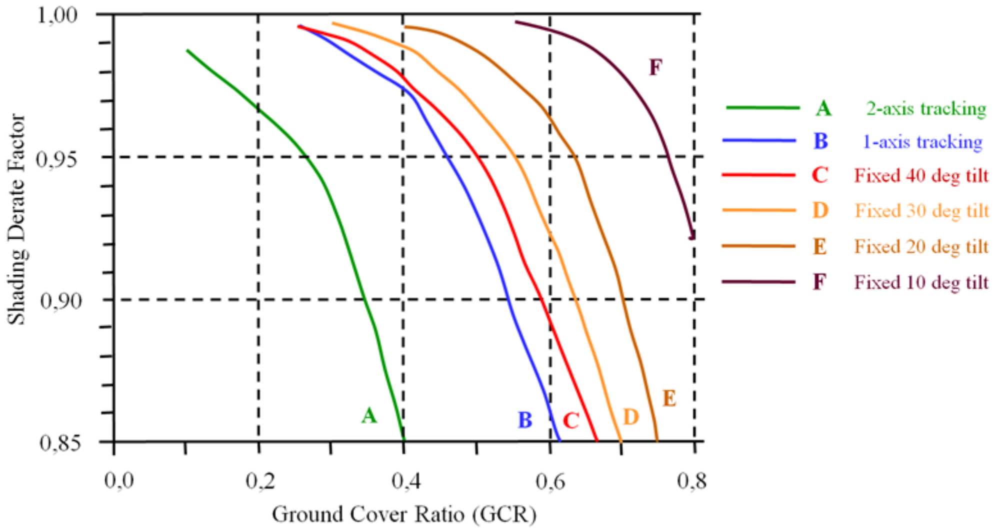



**Figure 4.** Shading derate factor versus ground cover ratio (GCR) for different tracking options and tilt angles (drawn, redrawn, generated and regenerated based on source PowerLight Corp. on [45] with Paint.NET.4.0.16 [31]).

- Snow Loss: "Reduction in the system's annual output due to snow covering the array." [45]
- Mismatch Loss: "Electrical losses due to slight differences caused by manufacturing imperfections between modules in the array that cause the modules to have slightly different current-voltage characteristics." [45]
- Wiring Loss: "Resistive losses in the DC and AC wires connecting modules, inverters, and other parts of the system." [45]
- Connections Loss: "Resistive losses in electrical connectors in the system." [45]
- Light-Induced Degradation Loss: "Effect of the reduction in the array's power during the first few months of its operation caused by light-induced degradation of photovoltaic cells." [45]
- Nameplate Rating Loss: "Nameplate rating loss accounts for the accuracy of the manufacturer's nameplate rating. Field measurements of the electrical characteristics of photovoltaic modules in the array may show that they differ from their nameplate rating." [45]
- Age Loss: "Effect of weathering of the photovoltaic modules on the array's performance over time" [45]
- Availability Loss: "Reduction in the system's output cause by scheduled and unscheduled system shutdown for maintenance, grid outages, and other operational factors." [45]

The soiling loss value of the Greenough River Solar Farm is determined based on some information on some specific documents such as "soiling: <%3/yr", and "monthly average actual measured soiling 0.31%" [46, 47]. This loss is mainly a PV panel technology, PV power plant site and PV power plant design specific loss.

The shading loss value of the Greenough River Solar Farm is determined in accordance with the SAM help manual ("Shading Loss" and Figure 4). The ground coverage ratio (GCR) is estimated based on the measurements on the Google Earth Pro 7.1.5.1557 in accordance with its description (GCR = A/B = approximately 2.20 m / 5.20 m measurement = 0.4231, actual A = 1.2 m, measurement accuracy: 1.20 m / 2.20 m = 54,54%) [48, 49]. Hence, the shading derate factor is read on the fixed 20 degree tilt curve from Figure 4 as 0,99 for the GCR of 0.4231. This loss is mainly a PV panel technology, PV power plant site and PV power plant design specific loss.

The snow loss value of the Greenough River Solar Farm is determined according to the climatic conditions of the precipitation and the snowfall of Geraldton and Mullewa in Western Australia [50-51]. This loss is mainly a PV panel technology, PV power plant site and PV power plant design specific loss.

The mismatch loss value of the Greenough River Solar Farm is determined based on some information on some specific documents such as "*1.0 % First Solar module performance guidance*" [47]. This loss is mainly a PV panel technology specific loss.

The wiring loss value of the Greenough River Solar Farm is determined according to the general PV literature and on some information on some specific documents "*DC Wiring derating factor: 0.98*" and "*AC Wiring derating factor: 0.99*" [47, 52-54]. This loss is mainly a PV power plant site and PV power plant design specific loss.

The connections loss value of the Greenough River Solar Farm is determined according to the general PV literature and on some information on some specific documents [47, 52-54]. This loss is mainly a PV power plant site and PV power plant design specific loss.

The light-induced degradation loss value of the Greenough River Solar Farm is determined according to the general PV literature and the catalogs of the First Solar Series 3 PV modules [41, 55-60]. This loss is mainly a PV panel technology specific loss.

The nameplate rating loss value of the Greenough River Solar Farm is determined according to the general PV literature and on some information on some specific documents [42, 60, 61]. This loss is mainly a PV panel technology specific loss.

The age loss value of the Greenough River Solar Farm is determined according to the general PV literature and the catalogs of the First Solar Series 3 PV modules [41, 55-60].

The availability rating loss value of the Greenough River Solar Farm is determined according to the Verve Energy documents "*Greenough River Solar Farm Pty Ltd, a joint venture partnership between Verve Energy and GE Energy Financial Services*", and "*Plant availability has been > than 99%*" [42, 61]. This loss is mainly a PV panel technology, PV power plant site, PV power plant design and all other issues specific loss.

There are 6 models related to the losses on the PVWatts V5, NREL SAM Version 2017.9.5 Revision 2 in this study. These 6 models are the "SAM Default Value Case (%)", the "Most Possible Value Case (%)", the "Reasonable Minimum Value Case (%)", the "Reasonable Maximum Value Case (%)", the "Case More Or Less According To Personal Communication (%)", and the "Case According To Total System Losses (%)". These 6 models and the losses on the PVWatts V5, NREL SAM Version 2017.9.5 Revision 2 are presented in Table 5. The models and actual (real life) observations major mismatch is expected in the losses issues.

## 3. Results and Discussion

The annual output data of the Greenough River Solar Farm is 22.000 MWh for the first 12 months period [42]. The annual output data of the Greenough River Solar Farm between 2013 and 2017 are gathered from the official records [63].

### 3.1. Actual Generation

The generation data in the form of Supervisory Control and Data Acquisition (SCADA) generation quantity is publicly available for all generation units in the South West Interconnected System (SWIS) of south-west Western Australia. The data is available as monthly comma separated variable (*.csv) files for half hourly trading intervals [64]. The data for the Greenough River Solar Farm is identified with a facility code of GREENOUGH_RIVER_PV1. The generation data has been aggregated into monthly figures with the exception of February 29, 2012 and 2016 as the NREL SAM works on a 365 day (8.760 hours).

**Table 5.** PVWATTS SAM Losses

| Losses | SAM Default Value Case (%) | Most Possible Value Case (%) | Reasonable Minimum Value Case (%) | Reasonable Maximum Value Case (%) | Case More or Less According to Personal Communication (%) | Case According to Total System Losses (%) | Core References |
|---|---|---|---|---|---|---|---|
| Soiling | 2 | 3 | 2 | 4 | 3 | - | [46,47] |
| [a]Shading | [a]3 | 0 | [a]1 | [a]4 | 0 | - | |
| Snow | 0 | 0 | 0 | 0 | 0 | - | [50-51] |
| Mismatch | 2 | 1 | 0.5 | 3 | 0 | - | [47] |
| [a]Wiring | [a]2 | [a]2 | [a]1 | [a]4 | 2 | - | [47,53-55] |
| [a]Connections | [a]0.5 | [a]0.5 | [a]0.3 | [a]1 | 0.5 | - | [47,53-55] |
| [a]Light-Induced Degradation | 1.5 | 0.9 | 0.5 | 4 | 0 | - | [41,56-61] |
| [a]Nameplate Rating | [a]1 | [a]2 | [a]0.5 | [a]3 | 0 | - | [41,61,62] |
| [a]Age | [a]0 | [a]2 | [a]1 | [a]3.5 | 0 | - | [41,56-61] |
| [a]Availability | [a]3 | [a]1 | [a]0 | [a]5 | 1 | - | [42,63] |
| [b,c] Total system losses | 14.08 | 11.77 | 6.63 | 27.47 | 6.36 | 15 | |

[a]Losses: These inputs are preliminary indicative values for finding the total system losses. They could not be crosschecked and confirmed yet. The readers should not use these losses in their scientific, engineering and commercial studies, before any further research studies presented in the literature. [b]Total system losses = 100%×{1-[(1-Soiling ÷ 100% )×(1-Shading÷100%)×(1-Snow÷100%)×(1-Mismatch÷100%)×(1-Wiring÷100%)×(1-Connections÷100%)×(1-Light-induced degradation÷100%)×(1-Nameplate÷100%)×(1-Age÷100%)×(1-Availability÷100%)]}, [c]Total system losses: The readers may use the value of this total system losses input in their scientific, engineering and commercial analysis in accordance with the assumptions, inputs, results, and findings of this study.

### 3.2. Simulations

There is a single NREL SAM Version 2017.9.5 Revision 2, SSC Version 180 file with 6 model sheets (Greenough River Solar Farm.sam) for each year in this study (totally 5 files 2013-2017). The sheets and acronyms of the NREL SAM Version 2017.9.5 Revision 2, SSC Version 180 file are SAMD for the "SAM Default Value Case (%)", MP for the "Most Possible Value Case (%)", RMIN for the "Reasonable Minimum Value Case (%)", RMAX for the "Reasonable Maximum Value Case (%)", PC for the "Case More Or Less According To Personal Communication (%)" and TSL for the "Case According To Total System Losses (%)". There are 2 different hardware options of the current simulations in this study. These are a Windows personal computer (PC) (Windows 10 Pro, Intel(R) Core(TM) i5 CPU 650 @ 3.20 GHz, 6,00 GB RAM) and a Linux personal computer (PC) (Ubuntu 17.10, AMD(R) A9-9430 Radeon r5, 5 compute cores 2c+3g×2@3.20 GHz, 7.8Gb RAM). The simulation report summaries are presented in Table 6, Table 7, Table 8.

### 3.3. SAM results and actual generation comparisons

In comparing model outputs from the NREL SAM to actual generation data one needs to take into account the actual system design and implementation decisions that are not covered by the model. In the case of the Greenough River Solar Farm, the system has a 10,00 MW export limit at the point of connection to the grid. However. to guarantee energy production the number of modules has been adjusted. To ensure the export limit is not exceeded the inverters have been "de-rated" to about 90% of their capacity. To cater for this in the modeling the SAM models have been run with an inverter efficiency of 90,00% [64]. Under this important circumstance. the simulation results are gathered and compared with only a few forecast accuracy metrics (i.e. scale-dependent errors: forecast errors ($e_t$). absolute forecast errors ($|e_t|$). Mean Absolute Error (MAE). Geometric Mean

**Table 6.** PVWATTS SAM Simulation Report of PC Windows 10 Pro, Intel(R) Core(TM) i5 CPU 650 @ 3.20 GHZ, 6,00 GB RAM with internet connection

| Model | | Total time (ms) | SSC time (ms) | Errors | Warnings | Notices | Annual energy (year 1) (kWh) | Capacity factor (year 1) (%) | Energy yield (year 1) (kWh/kW) |
|---|---|---|---|---|---|---|---|---|---|
| 2013 | [a]SAMD | 94 | 93 | 0 | 0 | 0 | 22.626.782 | 20.4 | 1.784 |
| | [b]MP | 68 | 67 | 0 | 0 | 0 | 23.157.658 | 20.8 | 1.826 |
| | [c]RMIN | 63 | 62 | 0 | 0 | 0 | 24.245.572 | 21.8 | 1.912 |
| | [d]RMAX | 62 | 62 | 0 | 0 | 0 | 19.137.884 | 17.2 | 1.509 |
| | [e]PC | 62 | 62 | 0 | 0 | 0 | 24.479.782 | 22.0 | 1.931 |
| | [f]TSL | 61 | 60 | 0 | 0 | 0 | 22.403.222 | 20.2 | 1.767 |
| 2014 | [a]SAMD | 68 | 67 | 0 | 0 | 0 | 22.493.822 | 20.3 | 1.774 |
| | [b]MP | 66 | 65 | 0 | 0 | 0 | 23.016.676 | 20.7 | 1.815 |
| | [c]RMIN | 63 | 62 | 0 | 0 | 0 | 24.092.986 | 21.7 | 1.900 |
| | [d]RMAX | 68 | 67 | 0 | 0 | 0 | 19.024.892 | 17.1 | 1.500 |
| | [e]PC | 63 | 62 | 0 | 0 | 0 | 24.328.382 | 21.9 | 1.919 |
| | [f]TSL | 62 | 61 | 0 | 0 | 0 | 22.272.894 | 20.1 | 1.757 |
| 2015 | [a]SAMD | 65 | 64 | 0 | 0 | 0 | 22.529.162 | 20.3 | 1.777 |
| | [b]MP | 62 | 61 | 0 | 0 | 0 | 23.069.198 | 20.8 | 1.819 |
| | [c]RMIN | 61 | 60 | 0 | 0 | 0 | 24.168.974 | 21.8 | 1.906 |
| | [d]RMAX | 60 | 59 | 0 | 0 | 0 | 19.041.522 | 17.1 | 1.502 |
| | [e]PC | 62 | 60 | 0 | 0 | 0 | 24.397.256 | 22.0 | 1.924 |
| | [f]TSL | 63 | 62 | 0 | 0 | 0 | 22.302.290 | 20.1 | 1.759 |
| 2016 | [a]SAMD | 63 | 62 | 0 | 0 | 0 | 22.511.598 | 20.3 | 1.775 |
| | [b]MP | 61 | 60 | 0 | 0 | 0 | 23.032.192 | 20.7 | 1.816 |
| | [c]RMIN | 60 | 59 | 0 | 0 | 0 | 24.107.520 | 21.7 | 1.901 |
| | [d]RMAX | 64 | 63 | 0 | 0 | 0 | 19.054.910 | 17.2 | 1.503 |
| | [e]PC | 62 | 61 | 0 | 0 | 0 | 24.346.238 | 21.9 | 1.920 |
| | [f]TSL | 62 | 61 | 0 | 0 | 0 | 22.293.418 | 20.1 | 1.758 |
| 2017 | [a]SAMD | 61 | 60 | 0 | 0 | 0 | 22.773.060 | 20.5 | 1.796 |
| | [b]MP | 66 | 65 | 0 | 0 | 0 | 23.313.812 | 21.0 | 1.839 |
| | [c]RMIN | 63 | 62 | 0 | 0 | 0 | 24.416.984 | 22.0 | 1.926 |
| | [d]RMAX | 64 | 63 | 0 | 0 | 0 | 19.257.092 | 17.3 | 1.519 |
| | [e]PC | 64 | 63 | 0 | 0 | 0 | 24.649.918 | 22.2 | 1.944 |
| | [f]TSL | 60 | 60 | 0 | 0 | 0 | 22.545.862 | 20.3 | 1.778 |

**Table 7.** PVWATTS SAM Simulation Report of PC Ubuntu 17.10. AMD(R) A9-9430 Radeon r5. 5 compute cores 2c+3g × 2 @ 3.20 GHz. 7.8Gb RAM with internet connection

| Model | | Total time (ms) | SSC time (ms) | Errors | Warnings | Notices | Annual energy (year 1) (kWh) | Capacity factor (year 1) (%) | Energy yield (year 1) (kWh/kW) |
|---|---|---|---|---|---|---|---|---|---|
| 2013 | [a]SAMD | 80 | 79 | 0 | 0 | 0 | 22.626.782 | 20.4 | 1.784 |
| | [b]MP | 75 | 73 | 0 | 0 | 0 | 23.157.658 | 20.8 | 1.826 |
| | [c]RMIN | 79 | 77 | 0 | 0 | 0 | 24.245.572 | 21.8 | 1.912 |
| | [d]RMAX | 73 | 72 | 0 | 0 | 0 | 19.137.884 | 17.2 | 1.509 |
| | [e]PC | 75 | 73 | 0 | 0 | 0 | 24.479.782 | 22.0 | 1.931 |
| | [f]TSL | 72 | 71 | 0 | 0 | 0 | 22.403.222 | 20.2 | 1.767 |
| 2014 | [a]SAMD | 77 | 75 | 0 | 0 | 0 | 22.493.822 | 20.3 | 1.774 |
| | [b]MP | 77 | 75 | 0 | 0 | 0 | 23.016.676 | 20.7 | 1.815 |
| | [c]RMIN | 78 | 76 | 0 | 0 | 0 | 24.092.986 | 21.7 | 1.900 |
| | [d]RMAX | 76 | 73 | 0 | 0 | 0 | 19.024.892 | 17.1 | 1.500 |
| | [e]PC | 80 | 78 | 0 | 0 | 0 | 24.328.382 | 21.9 | 1.919 |
| | [f]TSL | 81 | 78 | 0 | 0 | 0 | 22.272.894 | 20.1 | 1.757 |
| 2015 | [a]SAMD | 73 | 71 | 0 | 0 | 0 | 22.529.162 | 20.3 | 1.777 |
| | [b]MP | 77 | 75 | 0 | 0 | 0 | 23.069.198 | 20.8 | 1.819 |
| | [c]RMIN | 79 | 77 | 0 | 0 | 0 | 24.168.974 | 21.8 | 1.906 |
| | [d]RMAX | 72 | 71 | 0 | 0 | 0 | 19.041.522 | 17.1 | 1.502 |
| | [e]PC | 76 | 75 | 0 | 0 | 0 | 24.397.256 | 22.0 | 1.924 |
| | [f]TSL | 73 | 72 | 0 | 0 | 0 | 23.302.290 | 20.1 | 1.759 |
| 2016 | [a]SAMD | 79 (94) | 77 (92) | 0 | 0 | 0 | 22.511.598 | 20.3 | 1.775 |
| | [b]MP | 76 | 74 | 0 | 0 | 0 | 23.032.192 | 20.7 | 1.816 |
| | [c]RMIN | 72 | 71 | 0 | 0 | 0 | 24.107.520 | 21.7 | 1.901 |
| | [d]RMAX | 79 | 77 | 0 | 0 | 0 | 19.054.910 | 17.2 | 1.503 |
| | [e]PC | 82 | 80 | 0 | 0 | 0 | 24.346.238 | 21.9 | 1.920 |
| | [f]TSL | 77 | 76 | 0 | 0 | 0 | 22.293.418 | 20.1 | 1.758 |
| 2017 | [a]SAMD | 74 (98) | 73 (96) | 0 | 0 | 0 | 22.773.060 | 20.5 | 1.796 |
| | [b]MP | 78 | 76 | 0 | 0 | 0 | 23.313.812 | 21.0 | 1.839 |
| | [c]RMIN | 75 | 73 | 0 | 0 | 0 | 24.416.984 | 22.0 | 1.926 |
| | [d]RMAX | 78 | 76 | 0 | 0 | 0 | 19.257.092 | 17.3 | 1.519 |
| | [e]PC | 76 | 74 | 0 | 0 | 0 | 24.649.918 | 22.2 | 1.944 |
| | [f]TSL | 78 | 77 | 0 | 0 | 0 | 22.545.862 | 20.3 | 1.778 |

[a]SAMD: SAM Default Value Case (%). [b]MP: Most Possible Value Case (%). [c]RMIN: Reasonable Minimum Value Case (%). [d]RMAX: Reasonable Maximum Value Case (%). [e]PC: Case More Or Less According To Personal Communication (%).[f]TSL: Case According To Total System Losses (%).

**Table 8.** PVWATTS SAM Simulation Comparison

| Hardware Configurations | Average Total time | Average SSC time | Maximum Total time | Maximum SSC time |
|---|---|---|---|---|
| PC Windows 10 Pro. Intel(R) Core(TM) i5 CPU 650 @ 3.20 GHZ. 6.00 GB RAM with internet connection | 64.1 ms | 63.2 ms | 94 ms | 93 ms |
| PC Ubuntu 17.10. AMD(R) A9-9430 radeon r5. 5 compute cores 2c+3g × 2 @ 3.20 GHz. 7.8Gb RAM | 77.9 ms | 76.1 ms | 98 ms | 96 ms |
| Performance Ratio (1st PC/2nd PC) | 82.29% | 83.05% | 95.92% | 96.88% |

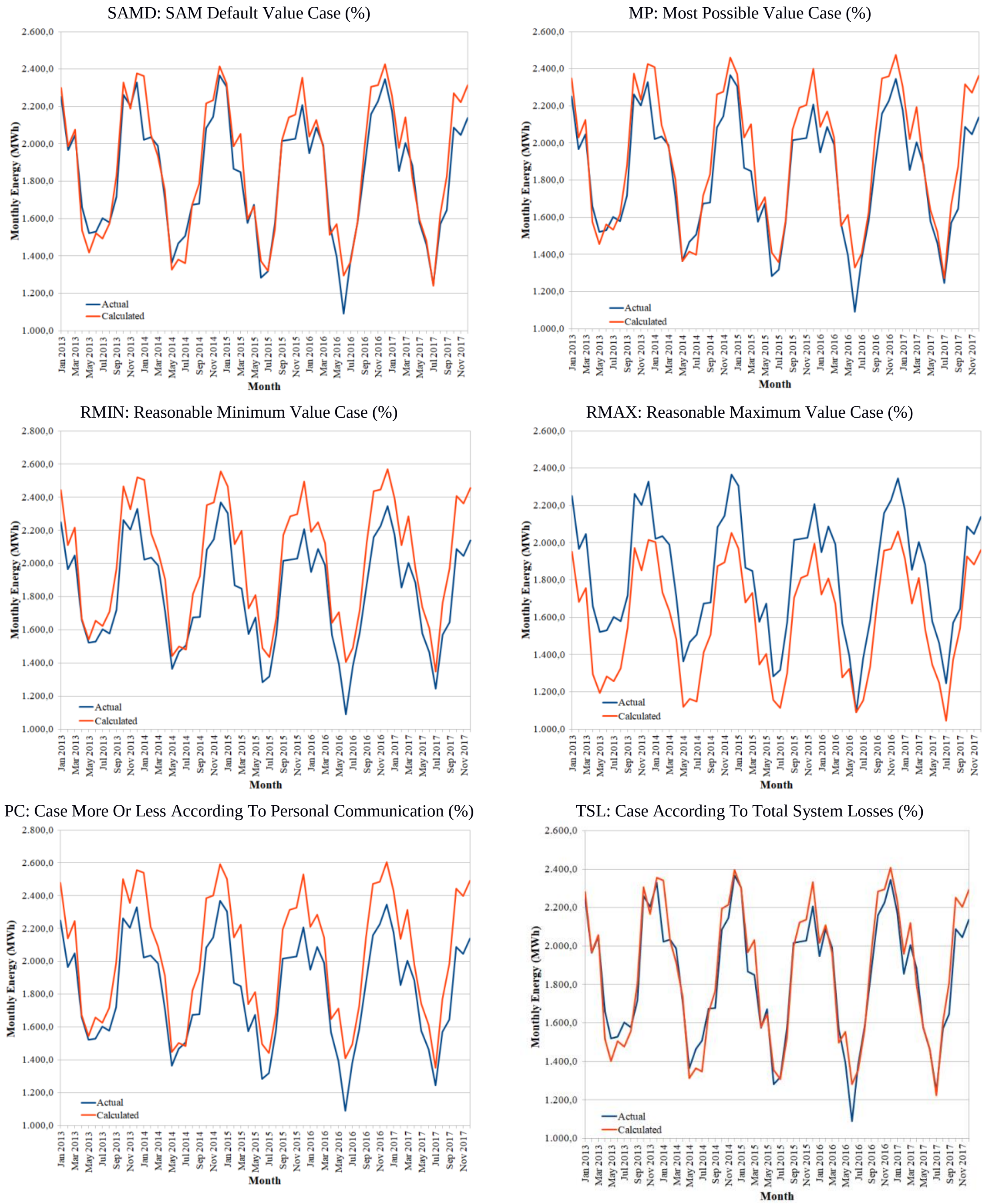



**Figure 5.** Greenough River Solar Farm Monthly SAM Results and Actual Generation Comparisons

Absolute Error (GMAE). Mean Square Error (MSE). Root Mean Square Error (RMSE); percentage errors: Absolute Percentage Errors (APE). Minimum Absolute Percentage Error (MinAP). Maximum Absolute Percentage Error (MAP). Mean Absolute Percentage Error (MAPE). Symmetric MAPE (SMAPE); relative errors: Relative Error (r_t). Median Relative Absolute Error (MdRAE). Geometric Mean Relative Absolute Error (GMRAE)) available in the literature and global unique forecast accuracy metrics pool of the Global Grid Prediction Systems (G2PS) (see [2. 26-29. 65-69]).

The SAMD, MP, RMIN, RMAX, PC, TSL vs. actual generation comparisons are presented in Figure 5. The whole data set "model/actual" values for SAMD, MP, RMIN, RMAX, PC, and TSL are respectively 102.9%, 105.3%, 110.3%, 87.0%, 111.3%, and 101.9%. In other words, the whole data set "model/actual" value differences are 2.9%, 5.3%, 10.3%, -13.0%, 11.3%, and 1.9%. Five models (SAMD, MP, RMIN, PC, TSL) have positive "model/actual" value deviations (bias). They overestimate the generation of the Greenough River Solar Farm. One model (RMAX) has negative "model/actual" value deviation (bias).

The TSL simulation and actual generation comparison of the Greenough River Solar Farm is given for a few forecast accuracy metrics in this paragraph (see Table 9 and Table 10). Others may be reviewed in the electronic supplementary files. The maximum forecast error ($e_t$) is observed in January 2014 (319,11 MWh). The minimum $e_t$ is observed in February 2013 (1,77 MWh). The absolute maximum forecast error ($|e_t|$) is observed in January 2014 (319,11 MWh). The absolute minimum $|e_t|$ is observed in February 2013 (1,77 MWh). The minimum mean absolute error (MAE) is 55,994 MWh in 2013. The maximum MAE is 88,479 MWh in 2017. The minimum geometric mean absolute error (GMAE) is 33,475 MWh in 2013. The maximum GMAE is 58,692 MWh in 2016. The minimum mean square error (MSE) is 64.588,220 MWh in 2013. The maximum MSE is 172.167,524 MWh in 2014. The minimum root mean square error (RMSE) is 254,142 MWh in 2013. The maximum RMSE is 414,931 MWh in 2014. The minimum absolute percentage error (MinAP) is 1.7775 in 2013. The maximum MinAP is 15,135 in 2016. The minimum maximum absolute percentage error (MAP) is 0.085 in 2013. The maximum MAP is 0.158 in 2014. The minimum mean absolute percentage error (MAPE) is 0.033 in 2013. The maximum MAPE is 0.049 in 2014 and 2016. The maximum model/actual is 17.4% in January 2016. The minimum model/actual is -10.7% in July 2014. The absolute minimum model/actual is 0.1% in February 2013. May 2017. The absolute maximum model/actual is 17.4% in January 2016. There is no seasonal prediction accuracy observed in this study.

**Table 9.** Greenough River PVWATTS SAM Simulations Forecast Accuracy

| | 2013 | | | 2014 | | | 2015 | | |
|---|---|---|---|---|---|---|---|---|---|
| Months | $e_t$ | $APE_t$ | Model/Actual | $e_t$ | $APE_t$ | Model/Actual | $e_t$ | $APE_t$ | Model/Actual |
| January | 30.52 | 0.014 | 1.01 | 319.12 | 0.158 | 1.16 | 3.36 | 0.001 | 1.00 |
| February | 1.78 | 0.001 | 1.00 | 2.84 | 0.001 | 1.00 | 100.16 | 0.054 | 1.05 |
| March | 8.60 | 0.004 | 1.00 | 73.56 | 0.037 | 0.96 | 181.12 | 0.098 | 1.10 |
| April | 141.36 | 0.085 | 0.91 | 27.46 | 0.016 | 1.02 | 3.27 | 0.002 | 1.00 |
| May | 118.80 | 0.078 | 0.92 | 51.44 | 0.038 | 0.96 | 27.19 | 0.016 | 0.98 |
| June | 24.20 | 0.016 | 0.98 | 101.46 | 0.069 | 0.93 | 74.63 | 0.058 | 1.06 |
| July | 126.54 | 0.079 | 0.92 | 160.98 | 0.107 | 0.89 | 11.04 | 0.008 | 0.99 |
| August | 20.94 | 0.013 | 0.99 | 20.38 | 0.012 | 0.99 | 48.24 | 0.031 | 0.97 |
| September | 92.00 | 0.054 | 1.05 | 88.01 | 0.052 | 1.05 | 19.10 | 0.009 | 0.99 |
| October | 44.08 | 0.019 | 1.02 | 108.60 | 0.052 | 1.05 | 99.83 | 0.049 | 1.05 |
| November | 36.43 | 0.017 | 0.98 | 67.44 | 0.031 | 1.03 | 108.19 | 0.053 | 1.05 |
| December | 26.69 | 0.011 | 1.01 | 28.33 | 0.012 | 1.01 | 126.79 | 0.057 | 1.06 |
| Total | 671.93 | 0.391 | 0.99 | 1.049.62 | 0.586 | 1.01 | 802.91 | 0.438 | 1.03 |

**Table 10.** Greenough River PVWATTS SAM Simulations Forecast Accuracy (continued)

| | 2016 | | | 2017 | | |
|---|---|---|---|---|---|---|
| Months | $e_t$ | $APE_t$ | Model/Actual | $e_t$ | $APE_t$ | Model/Actual |
| January | 67.67 | 0.035 | 1.03 | 60.53 | 0.028 | 1.03 |
| February | 20.71 | 0.010 | 1.01 | 102.54 | 0.055 | 1.06 |
| March | 29.36 | 0.015 | 0.99 | 115.97 | 0.058 | 1.06 |
| April | 69.81 | 0.045 | 0.96 | 85.04 | 0.045 | 0.95 |
| May | 159.16 | 0.114 | 1.11 | 2.14 | 0.001 | 1.00 |
| June | 190.02 | 0.174 | 1.17 | 2.38 | 0.002 | 1.00 |
| July | 26.18 | 0.019 | 0.98 | 20.35 | 0.016 | 0.98 |
| August | 15.14 | 0.010 | 0.99 | 36.89 | 0.023 | 1.02 |
| September | 90.52 | 0.048 | 1.05 | 161.07 | 0.098 | 1.10 |
| October | 125.10 | 0.058 | 1.06 | 164.45 | 0.079 | 1.08 |
| November | 69.02 | 0.031 | 1.03 | 155.91 | 0.076 | 1.08 |
| December | 62.11 | 0.026 | 1.03 | 154.46 | 0.072 | 1.07 |
| Total | 924.79 | 0.585 | 1.03 | 8.043.42 | 2.212 | 1.01 |

**Table 11.** Greenough River PVWATTS SAM Simulations Forecast Accuracy (annual)

| Years | MAE | GMAE | MSE | RMSE | MAP | SMAPE | MAPE |
|---|---|---|---|---|---|---|---|
| 2013 | 55.994 | 33.475 | 64.588.220 | 254.142 | 0.085 | 1.7% | 0.033 |
| 2014 | 87.468 | 53.684 | 172.167.524 | 414.931 | 0.158 | 2.4% | 0.049 |
| 2015 | 66.909 | 36.519 | 89.725.959 | 299.543 | 0.098 | 1.8% | 0.037 |
| 2016 | 77.066 | 58.692 | 105.561.063 | 324.902 | 0.174 | 2.3% | 0.049 |
| 2017 | 88.479 | 47.667 | 137.800.827 | 371.215 | 0.098 | 2.2% | 0.046 |

Table 11 summarizes the comparisons between actual generation and calculated generation and the degree of "fit" between both datasets on an hourly basis. Overall, there is a strong correlation between both datasets. The average correlation for the full datasets is 0.964. Removing all figures where both sets of data are zero, that is, removing non-generating hours, gives an average correlation of 0.928 ($R^2$: 0.860), which is still very strong. The average calculated generation is also of the same magnitude as the actual generation. Figure 6 is a scatter plot for 2017, showing the reasonably good fit between calculated and actual generation. These figures suggest the dataset and usage of the NREL SAM models are useful in evaluating the potential for PV generation in the south west of Western Australia (region nearby the Greenough River Solar Farm).

**Table 12.** Actual and Calculated Generation - Greenough River Solar Farm

| Year | Actual (MWh) | CF | Calc (MWh) | Calc CF | Corr | Calc/Actual | Avg. gen. hours/day | Corr.gen hours | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 2013 | 22.667,836 | 0.259 | 22.403,196 | 0.256 | 0.968 | 98.8% | 12.9 | 0.939 | 0.881 |
| 2014 | 22.044,605 | 0.252 | 22.272,910 | 0.254 | 0.958 | 101.0% | 12.3 | 0.914 | 0.836 |
| 2015 | 21.717,233 | 0.248 | 22.302,285 | 0.255 | 0.963 | 102.7% | 12.3 | 0.923 | 0.853 |
| 2016 | 21.649,592 | 0.247 | 22.293,418 | 0.254 | 0.964 | 103.0% | 12.3 | 0.926 | 0.858 |
| 2017 | 21.694,898 | 0.248 | 22.545,864 | 0.257 | 0.968 | 103.9% | 12.3 | 0.935 | 0.874 |
| Total | 109.774,164 | | 111.817,673 | | 0.964 | 101.9% | | 0.928 | 0.860 |

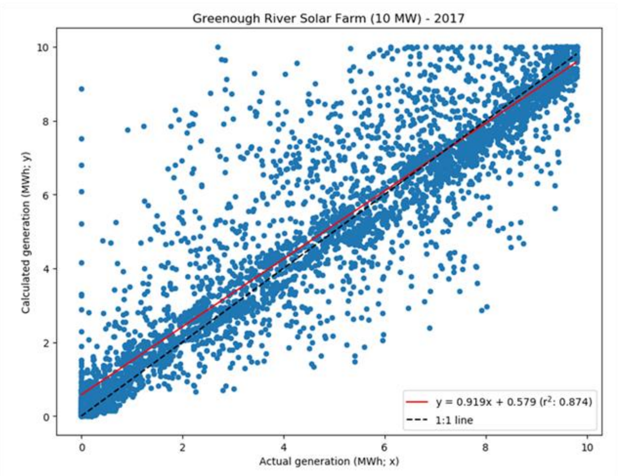



**Figure 6.** Greenough River Solar Farm 2017 SAM Results and Actual Generation Linear Fitting

## 4. Conclusions and Future Research Studies

This initial research study presents the first validation and verification effort of the PVWatts V5 model on the NREL SAM Version 2017.9.5 Revision 2, SSC Version 180 performance models at the Greenough River Solar Farm like SEGS VI, Topaz Solar Farm and Solar Star Projects [2, 68]. There are some strengths and weaknesses of this research study. Some of the strengths are related to the information gathered for the modelling during this research study and using one of the most applied modelling tools and algorithms. Some of the weaknesses are related to the unavailable field losses data such as mismatch (%) and the weather source data.

The novelty of the obtained results in this research study is its presentation of the simulation and actual PVPP generation values and the values of the forecast accuracy metrics not only on an annual basis, but also the whole operational period of a PVPP with its uniqueness of being the first validation and verification research effort of the PVWatts V5 model on the NREL SAM Version 2017.9.5 Revision 2, SSC Version 180 performance models at the Greenough River Solar Farm (the first research study), and also being the first validation and verification research effort of a PVPP in the south west of Western Australia region of the World (the first research study) with different expert evaluations on the system losses by the first usage of NASA MERRA-2 dataset (the first research study) on two different PCs (the first research study). The best simulation performed absolute model/actual model is TSL with a deviation of 1.9%, which is almost excellent forecast estimation.

Also, an interesting contribution of this research study is in the research, development, demonstration and deployment ($RD^3$) efforts of VLPVPP on the World and also the $G^2PS$, the $G^2EDPS$, the $G^2P^3S$, the $G^3SPS$, the $G^3SEGPS$, the $G^3SP^3S$, the $G^3SCPS$, the $G^2CSPS$, the $G^2CSEDPS$, the $G^2CSP^3S$, the $G^2CSP^2S$ [36-29, 65, 69].

In the next research studies, the system management and configuration and also the hourly generation data of the Greenough River Solar Farm will be tried to be found from the operators, and owners, the planned expansion (40 MW) power plant will be modelled and future generation figures will be forecast or projected to guide the investors. The detailed photovoltaic (PV) model in the latest NREL SAM version will be studied and run to compare this model. The core aim of all of these efforts is for researching and developing an autonomous and automatic design tool on Geographic Information Systems (GIS) by an artificial intelligence approach at the end.

***Acknowledgment***

*The authors would sincerely like to express their thankfulness to Craig Carter, and Andreas Wade for guidance and help.*

**Nomenclature**

AC: Alternating Current
Avg. gen. hours/day : Average Generation Hours/Day
APE: Absolute Percentage Errors (percentage error)
CdTe: Cadmium Telluride
Calc: Calculated Generation (kWh, MWh)
Calc/Actual: Calculated Generation/Actual Generation
Calc CF: Calculated Capacity Factor
CEC: California Energy Commission
CF:Capacity Factor
Corr: Correlation
Corr. gen. hours: Correlation Generation Hours
CPU: Central Processing Unit
DC: Direct Current
DC:AC ratio: Direct Current Alternating Current Ratio
DHI: Direct Horizontal Insolation, Direct Horizontal Irradiance (W/m$^2$)
DNI: Direct Normal Insolation, Direct Normal Irradiance (W/m$^2$)
$e_t$: Forecast Error (scale-dependent error) (MWh)
$|e_t|$: Absolute Forecast Error (scale-dependent error) (MWh)
FS: First Solar
GB: Gigabyte
GCR: Ground Cover Ratio
$G^2$EDPS: Global Grid Electricity Demand Prediction System
GHI: Global Horizontal Insolation, Global Horizontal Irradiance (W/m$^2$)
GHZ or GHz: Gigahertz
$G^2$PS: Global Grid Prediction Systems
$G^2P^3$S: Global Grid Peak Power Prediction System
$G^2$CSPS: Global Grid Consumption Side Prediction Systems
$G^2$CSEDPS: Global Grid Consumption Side Electricity Demand Prediction System
$G^2CSP^3$S: Global Grid Consumption Side Peak Power Prediction System
$G^2CSP^2$S: Global Grid Consumption Side Price Prediction System
GMAE: Geometric Mean Absolute Error (scale-dependent error) (MWh)
GMRAE: Geometric Mean Relative Absolute Error (relative error) (MWh)
$G^3$SCPS: Global Grid Generation Side Cost Prediction System
$G^3$SEGPS: Global Grid Generation Side Electricity Generation Prediction System
$G^3$SPS: Global Grid Generation Side Prediction Systems
$G^3SP^3$S: Global Grid Generation Side Peak Power Prediction System
GIS: Geographic Information Systems
km$^2$: Square Kilometer or Square Kilometer
LPVPPs: Large Photovoltaic Solar Power Plants
MAE: Mean Absolute Error (scale-dependent error) (MWh)
MAP: Maximum Absolute Percentage Error (percentage error) (%)
MAPE: Mean Absolute Percentage Error (percentage error) (%)
MdRAE: Median Relative Absolute Error (relative error)
MERRA-2: Modern-Era Retrospective Analysis for Research and Applications Version 2
MinAP: Minimum Absolute Percentage Error (percentage error) (%)
Mono-Si: Monocrystalline Silicon
MP: Most Possible Value Case (%)
Ms: milliseconds
MSE: Mean Square Error (scale-dependent error) (MWh)
MW: Megawatt
$MW_{AC}$: Megawatt Alternating Current
$MW_{DC}$: Megawatt Direct Current
MWh: Megawatt hour(s)
NASA: National Aeronautics and Space Administration
NREL: National Renewable Energy Laboratory
PC: Case More Or Less According To Personal Communication (%)
PCs: Personal Computers
PV: Photovoltaic
PVPP: Photovoltaic Solar Power Plant
RAM: Random Access Memory
$r_t$: Relative Error (relative error)
$R^2$ : R squared (coefficient of determination)
RD$^3$: Research, Development, Demonstration and Deployment
RMAX: Reasonable Maximum Value Case (%)
RMIN: Reasonable Minimum Value Case (%)
RMSE: Root Mean Square Error (scale-dependent error) (MWh)
SAM: System Advisor Model
SAMD: SAM Default Value Case (%)
SCADA: Supervisory Control and Data Acquisition
sc-Si: Monocrystalline Silicon
SMAPE: Symmetric MAPE (percentage errors) (%)
SWIS: South West Interconnected System
TSL: Case According To Total System Losses (%)
U.S.A.: The United States of America
UW: University of Wisconsin
VLPVPPs : Very Large Photovoltaic Solar Power Plants

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