

J. Wang, B. Lu, K. Yu, M. Tian, X. Huang and Z. Wang, "Rice growth monitoring using multi-temporal GF-1 images," *2017 6th International Conference on Agro-Geoinformatics*, Fairfax, VA, 2017, pp. 1-5.

doi: 10.1109/Agro-Geoinformatics.2017.8047018

Abstract: With China Remote Sensing career advancement, a large number of independent researches and development satellites have launched. Among a new generation of high-resolution satellites, GaoFen-1 (GF-1) stands out. It sets high spatial resolution (2 m-16 m), multi-spectral and high temporal resolution (4-day) with 60 km-800 km swath in a fusion technology with strategic significance. In order to explore the adaptability of Chinese GF-1 images in rice growth monitoring, aboveground biomass (AGB) was considered as plant growth indicator. Multi-temporal GF-1 WFV images of Xinghua City, Jiangsu Province were selected for rice growth parameter retrieval. An extensive field campaign was carried out during the rice growing season in 2015. Six rice sample plots with areas larger than $200 \times 200 \text{ m}^2$ in Xinghua City were randomly chosen in order to measure the vegetation characteristics. Only cloud-free images were selected for AGB modeling. Using Savitzky-Golay filters, daily vegetation indices (VIs) time series were created from all the GF-1 images. For modeling of AGB from GF-1, there were 42 matching AGB sample sites. The matched cumulative VIs were calculated from 10-day composite data and were adopted for the estimation of AGB. Five traditional regression equations (linear, exponential, power, logarithmic, and quadratic polynomial regression) were applied in model construction. The leave-one-out cross-validation method was implemented to test the prediction capability of the models. The cumulative NDVI-based quadratic polynomial fit function was adopted for the prediction of AGB at all stages. In this paper, the application provided an important reference of field management and decision-making information. Indicated that GF-1 satellite's high time resolution provides chances to get cloudless data, and high spatial and spectral resolution features can replace the traditional medium resolution remote sensing of agricultural growth monitoring data to a certain extent, but a lot of ground survey data still needed to improve model and monitoring accuracy. This research shows that GF-1 WFV is an important data source and the data's application in other areas of agriculture is the focus of future research.

keywords: {geophysical image processing;regression analysis;time series;vegetation mapping;10-day composite data;AGB model;AGB sample site;China remote sensing;Xinghua City;cloud-free image;daily vegetation indices time series;extensive field campaign;high spatial resolution feature;high-resolution GaoFen-1 satellite;image matching;medium resolution remote sensing;multitemporal Chinese GF-1 image;multitemporal GF-1 WFV image;plant growth indicator;quadratic polynomial fit function;quadratic polynomial regression;rice growing season;rice growth monitoring;rice growth parameter retrieval;rice sample plot;spectral resolution feature;Agriculture;Biomass;Mathematical model;Monitoring;Remote sensing;Spatial resolution;Vegetation mapping;GF-1 WFV images;aboveground biomass (AGB);cumulative vegetation indices;rice growth monitoring},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8047018&isnumber=8046248>

S. Bouaddi, I. Ahmed and O. A. mensour, "Modeling and prediction of reflectance loss in CSP plants using a non linear autoregressive model with exogenous inputs (NARX)," *2016 International Renewable and Sustainable Energy Conference (IRSEC)*, Marrakech, 2016, pp. 706-709.

doi: 10.1109/IRSEC.2016.7984071

Abstract: Dust buildup on the surface of reflectors is a major challenge facing concentrated solar power (CSP) plants deployed in the MENA (Middle East and North Africa) region. Soiled CSP reflectors cause the efficiency of the solar field to drop. Thus, monitoring the loss of reflectance is essential to develop adequate cleaning strategies and evaluate the economics of the plants. The goal of this study is to model and predict the loss of reflectance in CSP plants. For this purpose, we modeled the loss of reflectance of second surface silvered glass mirrors exposed for 6 months in southwest Morocco using the non linear autoregressive with exogenous inputs (NARX) and Bayesian regularization. First, we adopted various architectures by varying the number of neurons in the hidden layer and adopting multiple tapped delay line. Then, we selected the optimal model based on the correlation coefficient (R) and the mean square error (MSE). The results revealed that the optimal model has 30 neurons in the hidden layer and 2 time delays, with a mean square error $\text{MSE} = 0.029$ and an overall $R_{\text{tot}} = 0.62$. To verify this model adequacy for the prediction of future reflectance data, we tested it on completely new data. The forecasting performance of the optimal model resulted in a mean square forecasting error of $\text{MSE}_f = 0.049$.

Generally, the forecasted reflectance values are quite good and follow the expected soiling pattern.

keywords: {Bayes methods;autoregressive processes;correlation methods;mean square error methods;mirrors;power system economics;power system simulation;retroreflectors;soil;solar energy concentrators;solar power stations;Bayesian regularization;CSP plant;MENA region;Middle East and North Africa region;NARX;concentrated solar power plant;correlation coefficient;exogenous inputs;mean square forecasting error;nonlinear autoregressive model;plant economics;reflectance loss;reflector surface;second surface silvered glass mirror;soiled CSP reflector;southwest Morocco;Data models;Forecasting;Mathematical model;Mirrors;Predictive models;Reflectivity;Training;CSP;NARX;soiling;time series},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7984071&isnumber=7983856>

M. A. F. B. Lima *et al.*, "Portfolio theory applied to solar and wind resources forecast," in *IET Renewable Power Generation*, vol. 11, no. 7, pp. 973-978, 6 7 2017.

doi: 10.1049/iet-rpg.2017.0006

Abstract: Power generation from decentralised renewable energy (RE) sources has been increasingly used worldwide. The authors apply portfolio theory (PT) to solar and wind resource forecast, combining those two intermittent RE sources in different percentages to investigate the resultant effects on the prediction error with the use of a proposed impact factor. They use solar and wind data from a weather station in Brazil's Northeast region. The use of PT to improve resource forecast of the specific solar and wind conditions found in that Brazilian region is a pioneer project and an original contribution of their research. Traditionally, PT has been used in the finance sector to reduce investment risks by diversifying applications. Considering predictability, the efficient frontier indicates an optimum portfolio for the period under investigation composed by 30% solar and 70% wind resource, obtained by the smallest calculated standard deviation. The obtained average forecast error for wind speed was -1.54% and for solar irradiance was 3.16%; the average forecast error resulting from the integration of 30% solar and 70% wind was -0.13%. This study innovates by using PT to solar and wind forecast in the planning phase, before the installation of wind and solar plants.

keywords: {solar power stations;wind power plants;Brazilian region;PT;forecast error;portfolio theory;solar irradiance;solar plants;solar resources forecast;wind conditions;wind plants;wind resources forecast;wind speed},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7956745&isnumber=7956727>

R. M. Ehsan, S. P. Simon and P. R. Venkateswaran, "Artificial neural network predictor for grid-connected solar photovoltaic installations at atmospheric temperature," *2014 International Conference on Advances in Green Energy (ICAGE)*, Thiruvananthapuram, 2014, pp. 44-49.

doi: 10.1109/ICAGE.2014.7050142

Abstract: An increase in environmental awareness, renewable energy usage and concern for energy security have resulted in the advent of Solar Photovoltaic (PV) systems as a sustainable form of alternative energy. Lack of area-specific forecasts for the power output of grid-connected photovoltaic system hinders in tapping the full potential of abundant solar power. The objective of this paper is to estimate the profile of power output of a grid connected 20kW_p solar power plant in a reputed manufacturing industry located in Tiruchirappalli, India [10° 44' 42.3816" N, 78° 47' 9.4524" E] using artificial intelligence techniques. An Artificial Neural Network (ANN) based model is proposed as a prediction model in this paper. An experimental database comprising of each day's solar power output and atmospheric temperature (from 31st May 2014 to 31st July 2014) has been used for training the ANN. The regression mapping of the neural network was carried out with the Neural Network Fitting Toolbox of MATLAB and simulated with Neuro Solutions development environment. Statistical error analysis in terms of Mean Squared Error (MSE) was calculated on the Day-Ahead Forecasting results and was found to be in the range of 0.019 to 0.025, signifying good accuracy and efficiency. Reliable area-specific solar power production map can provide better utilization of solar energy resource and help in power system management.

keywords: {least mean squares methods;load forecasting;neural nets;photovoltaic power systems;power engineering computing;regression analysis;solar power stations;ANN;India;MATLAB;MSE;Tiruchirappalli;artificial intelligence techniques;artificial neural network predictor;atmospheric temperature;day-ahead forecasting;grid connected solar power plant;grid-connected solar photovoltaic installations;mean squared error;neural network fitting toolbox;neuro solutions development environment;power system management;regression mapping;statistical error analysis;Artificial neural networks;Atmospheric modeling;Photovoltaic systems;Predictive models;Temperature measurement;Training;Artificial neural network;Atmospheric Temperature;Day-Ahead Forecasting;Mean Squared Error;Photovoltaic systems},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7050142&isnumber=7050131>

Z. Wang, L. He, X. Cheng and J. He, "Method for short-term photovoltaic generation power prediction base on weather patterns," *2014 China International Conference on Electricity Distribution (CICED)*, Shenzhen, 2014, pp. 213-215.

doi: 10.1109/CICED.2014.6991696

Abstract: This paper proposes a practical and effective method base on weather patterns for producing 15-minutes short-term prediction of photovoltaic generation with a prediction horizon of 24 hours. Two different radiation prediction models are examined for two different weather patterns. In the clear sky model, the surface radiation is predicted by calculating the cutting plane instantaneous intensity of solar radiation and atmospheric transparency coefficient. In the mode of non-clear sky, future radiation is forecasted by finding the quadratic curve of the measured surface radiation and the time. Finally, the radiation - power conversion model is developed to calculate the corresponding power prediction through the outputting of the short-term radiation prediction model. The proposed approach been applied in many PV power plant in the Northwest part of China. It is shown that the system can produce reasonable forecast results, providing a good guidance for dispatching and efficient running for PV power plant.

keywords: {photovoltaic power systems;power generation dispatch;solar radiation;weather forecasting;China;PV power plant;atmospheric transparency coefficient;clear sky model;power conversion model;quadratic curve;radiation prediction model;short-term photovoltaic generation power prediction method;solar radiation cutting plane instantaneous intensity calculation;surface radiation prediction;weather pattern;Abstracts;Clouds;Meteorology;Monitoring;Predictive models;Statistical analysis;forecasting method;photovoltaic generation power prediction;short-term prediction;solar radiation forecast;weather patterns},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6991696&isnumber=6991649>

C. W. Lu, C. Y. Hsieh and C. T. Chiang, "A Recurrent S_CMAC_GBF based estimation for global solar radiation from environmental information," *The 2010 International Joint Conference on Neural Networks (IJCNN)*, Barcelona, 2010, pp. 1-5.

doi: 10.1109/IJCNN.2010.5596963

Abstract: In recent years, from Europe to worldwide, installing Photovoltaic (PV) systems become a trend. The installing is not only increasing in larger systems but also in power plants. When the total installation capacity is getting enlarged, the power allocation and scheduling is getting more important. The prediction of the solar radiation is very important to PV system power generation, and PV power generation has effects on the power allocation, scheduling and the stability of the power net. This paper provides an efficient solar radiation prediction model, and it is useful to predict an installed PV system power generation or to evaluate a to-be-installed grid-connected system. The most effective factor of PV system stability is the solar radiation; it affects a PV system's voltage and current. Therefore, base on Recurrent S_CMAC_GBF, this project utilizes the easier measurable meteorological parameters to estimate the solar radiation to accurately calculate PV system's annual power generation. This research applied the information of the sunshine duration, relative humidity and temperature in Taiwan Taipei from 1998 to 2009 to verify the feasibility and accuracy of the developed model.

keywords: {cerebellar model arithmetic computers;estimation theory;humidity;installation;photovoltaic power systems;power engineering computing;power generation scheduling;power grids;power plants;solar radiation;Europe;Taiwan Taipei;cerebella model articulation controller;environmental information;general basis function;global solar radiation;grid-connected system;installation capacity;meteorological parameters;photovoltaic power generation;photovoltaic system installation;power allocation;power plants;power scheduling;recurrent S_CMAC_GBF based estimation;relative humidity;sunshine duration;Predictive models;Strontium;Testing;Training},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5596963&isnumber=5595732>

A. Dhoke, R. Sharma and T. K. Saha, "Condition monitoring of a large-scale PV power plant in Australia," *2016 IEEE Power and Energy Society General Meeting (PESGM)*, Boston, MA, 2016, pp. 1-5.

doi: 10.1109/PESGM.2016.7742048

Abstract: This paper considers the problems of condition monitoring and fault detection in an existing solar photovoltaic (PV) plant in Australia. A PV prediction model is proposed to accurately model the PV plant output. This model is then used with three condition monitoring and fault detection methods. The considered methods involve comparison of measured and modeled voltage and current ratios with appropriate thresholds and adjacent string values. The procedure to calculate thresholds is described. The proposed PV model and the condition monitoring approaches are collectively used with real PV data. As a result, the string disconnection and bypassed module faults are detected. It is also found that the string level monitoring is ideally suited for reliable condition monitoring and fault detection especially for large PV plants.

keywords: {condition monitoring;fault diagnosis;photovoltaic power systems;power plants;Australia;condition monitoring;large-scale PV power plant;solar photovoltaic plant;string disconnection;Circuit faults;Condition monitoring;Fault detection;Monitoring;Predictive models;Temperature measurement;Voltage measurement;Condition monitoring;PV systems;fault detection;string monitoring},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7742048&isnumber=7741056>

T. Mutaz and A. Ahmad, "Solar Radiation Prediction Using Radial Basis Function Models," *2015 International Conference on Developments of E-Systems Engineering (DeSE)*, Duai, 2015, pp. 77-82.

doi: 10.1109/DeSE.2015.55

Abstract: Accurate weather information is essential for developing an efficient solar power generation system. In this study one year hourly meteorological data for Kaitaia, New Zealand has been obtained from The National Climate Database of New Zealand to predict solar radiation. Twelve models with different combinations of input variables were formed. Three artificial neural networks (ANN), Multilayer Perceptron (MLP), Nonlinear Autoregressive Network with Exogenous Inputs (NARX), and Radial Basis Function (RBF) using Levenberg-Marquardt (LM) back propagation learning algorithm were trained and tested for the twelve models. The performance of each approach was assessed by calculating mean square error (MSE) and regression values. The results shows that models with a higher number of input variables irrespective of the number of neurons and delays provide better accuracy and improved results for regression values. In addition, the RBF network outperforms the NARX and MLP approaches. Furthermore, the 24-hour and 4-day ahead predicted solar radiation values of the RBF, NARX and MLP approaches are presented and, the results shows that the RBF network performs better than NARX and MLP approaches.

keywords: {atmospheric radiation;atmospheric techniques;Kaitaia;Levenberg-Marquardt back propagation learning algorithm;MLP solar radiation value;NARX solar radiation value;National Climate Database;New Zealand;RBF solar radiation value;accurate weather information;artificial neural networks;mean square error;multilayer perceptron;nonlinear autoregressive network with exogenous inputs;radial basis function;radial basis function models;regression values;solar power generation system;solar radiation prediction;year hourly meteorological data;Analytical models;Biological system modeling;Input variables;Neurons;Predictive models;Solar radiation;Time measurement;MLP;MSE;MultilayerPerceptron;NARX;artificial neural network model;prediction model;radial basis

function;regression analysis;solar radiation},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7563617&isnumber=7563596>

Y. Zhang *et al.*, "A strategy for day-ahead prediction of residual capacity of energy storage unit of micro grid in islanded state," *2016 IEEE International Conference on Mechatronics and Automation*, Harbin, 2016, pp. 2652-2657.

doi: 10.1109/ICMA.2016.7558985

Abstract: Research on energy management strategy is particularly important in the microgrid operation, especially in the isolated island operation state caused by external power grid fault or power quality unsatisfied with the requirements. Due to the uncertain of wind power and photovoltaic power output and deviation in load forecasting, it will make the energy storage unit of microgrid in islanded state frequently charge and discharge, which reduce power supply reliability of the microgrid and service life of energy storage unit, cause unnecessary energy loss and other problems. Through the analysis of two kinds of control mode of islanding operation of micro grid, this paper proposes a strategy for day-ahead forecasting of residual capacity of energy storage unit of microgrid in islanded state, using day-ahead prediction results of wind power and photovoltaic power. Then by calculating and analysis, we can obtain output instruction curve of the next day energy storage unit and optimize control scheme of energy management system of the storage energy unit, reduce the charge and discharge times and increases service life of the energy storage unit, so that to achieving the optimal configuration of a microgrid energy. Finally, this paper acquire the typical daily day-ahead forecasting of residual capacity curve of the microgrid in islanded operation by example analysis.

keywords: {distributed power generation;energy management systems;energy storage;load forecasting;photovoltaic power systems;wind power plants;day-ahead forecasting;day-ahead prediction;energy management system;energy storage unit;islanded state;microgrid;photovoltaic power;residual capacity;wind power;Discharges (electric);Energy storage;Inverters;Load forecasting;Microgrids;Solar power generation;Wind power generation;The energy storage unit of microgrid;day-ahead prediction;residual capacity;the islanded operation and new energy},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7558985&isnumber=7558523>

V. Abrukov, V. Kochakov, A. Smirnov, S. Abrukov and D. Anufrieva, "Knowledge-based system is a goal and a tool for basic and applied research," *2015 9th International Conference on Application of Information and Communication Technologies (AICT)*, Rostov on Don, 2015, pp. 60-63.

doi: 10.1109/ICAICT.2015.7338517

Abstract: From the data to the Knowledge is the main topic of the paper. Knowledge-Based System is the analytical and calculation tool that: contains all relationships between all variables of the object; allows to calculate the values of one part of variables through others; allows to solve direct and inverse problems; allows to predict the characteristics of an object that have not been investigated yet; allows to predict technology parameters to obtain an object with desired characteristics. This paper presents a methodology for a creation of the Knowledge-Based System of metamaterials based on nanofilms of linear-chain carbon by means of artificial neural networks as well as the descriptions in brief of other examples of Knowledge-Based Systems in various fields of basic and applied research such as combustion processes, inverse problems of optics, solar power plant, socio-economic systems, etc. All steps of the creation of the Knowledge-Based System of metamaterials as well as and illustrations are presented on the Web-site of the paper as the autonomous computer modules. Anyone can download the modules and execute research on their own and obtain all graphs which depict relationship between all variables of the concrete metamaterial.

keywords: {concrete;knowledge based systems;materials science computing;metamaterials;neural nets;analytical tool;artificial neural networks;autonomous computer modules;calculation tool;combustion processes;concrete metamaterial variables;direct problems;inverse problems;knowledge-based system;linear-chain carbon nanofilms;object characteristics prediction;object variables;optics;socio-economic systems;solar power plant;Artificial neural networks;Combustion;Computational modeling;Data models;Inverse problems;Knowledge based systems;Predictive models;Knowledge-based systems;artificial neural networks;combustion;experimental data;inverse problems;metamaterials;multifactor computational models;nanotechnology;socioeconomic systems;solar power plant},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7338517&isnumber=7338496>

P. Shen, Q. Chen and L. Xu, "Electrical characteristics prediction of microsatellite photovoltaic subsystem in orbit," *2015 IEEE Energy Conversion Congress and Exposition (ECCE)*, Montreal, QC, 2015, pp. 3287-3294.

doi: 10.1109/ECCE.2015.7310123

Abstract: Analyzing the performance of satellite photovoltaic (PV) array before launch and in space missions is crucial for energy balance and missions success. This study proposes a specific method to predict the electrical characteristics of body mounted solar array for microsatellite. Based on limit data provided by manufacturers and semiconductor band gap, the equivalent circuit model and its parameters of PV cell or module at different solar irradiance and temperature conditions are determined. Moreover, solar irradiance on body-mounted solar panel is modeled by the variation of incident angle in time domain. According to thermal balance relationship in orbit, the temperature fluctuation is modeled and computed by the Ronge-Kutta algorithm. Finally, calculated results are compared with measure data of the TX-1 microsatellite developed by Nanjing University of Aeronautics and Astronautics, and applied to predict output power in different space missions.

keywords: {Runge-Kutta methods;photovoltaic power systems;solar cell arrays;solar power satellites;space vehicle power plants;time-domain analysis;PV array;PV cell;Ronge-Kutta algorithm;TX-1 microsatellite;body mounted solar array;body-mounted solar panel;electrical characteristics prediction;equivalent circuit model;incident angle variation;microsatellite photovoltaic subsystem;satellite photovoltaic array performance analysis;semiconductor band gap;solar irradiance;space missions;temperature conditions;temperature fluctuation;thermal balance relationship;time domain;Arrays;Integrated circuit modeling;Mathematical model;Orbits;Photonic band gap;Photovoltaic cells;Temperature;body moun ted;electrical performance;modeling;sola r array},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7310123&isnumber=7309651>

B. R. Ke, T. T. Ku, Y. L. Ke, C. Y. Chuang and H. Z. Chen, "Sizing the Battery Energy Storage System on a University Campus With Prediction of Load and Photovoltaic Generation," in *IEEE Transactions on Industry Applications*, vol. 52, no. 2, pp. 1136-1147, March-April 2016.

doi: 10.1109/TIA.2015.2483583

Abstract: In this paper, the charge and discharge strategies were conducted for a future battery energy storage system (BESS) at the National Penghu University of Science and Technology, Makung, Taiwan. OpenDSS software was used to establish the power distribution system. A probabilistic neural network model was used to predict the daily load and photovoltaic (PV) generation curve for controlling the charge-discharge of the BESS. This study considered both the actual and predicted values of PV generation systems as well as the daily charge-discharge control of the BESS used to balance the peak and off-peak electricity consumption to shave peak loads under the two- and three-phase electricity-pricing methods. The average monthly electric bill and contract capacity were calculated, and the effects of different BESS capacities from the load curve were observed. The results were used to evaluate and determine the capacity required by the BESS. The prediction errors for the load and PV generation of the year were 6.22% and 7.14%, respectively. The electric bills and contract capacities of the actual and predicted values were compared, and the resulting difference was low; this implies that the proposed prediction method is practicable.

keywords: {battery storage plants;distribution networks;load forecasting;neural nets;photovoltaic power systems;power consumption;power engineering computing;power generation economics;pricing;BESS;Makung Taiwan;National Penghu University of Science and Technology;OpenDSS software;PV generation;battery energy storage system;charge-discharge control;contract capacity;electric bill;electricity consumption;load curve;load prediction;photovoltaic generation;power distribution system;probabilistic neural network model;three-phase electricity pricing method;two-phase electricity pricing method;university campus;Buildings;Contracts;Energy storage;Pricing;Software;Solar power generation;Wind power generation;BESS Capacity;Battery energy storage system (BESS) capacity;OpenDSS;PV Generation;Power Load;Prediction;photovoltaic (PV) generation;power load;prediction},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7283617&isnumber=7435355>

F. Bonanno, G. Capizzi and G. L. Sciuto, "Improved SMPS modeling for photovoltaic applications by a novel neural paradigm with Hamiltonian-based training algorithm," *2015 International Conference on Clean Electrical Power (ICCEP)*, Taormina, 2015, pp. 723-730.

doi: 10.1109/ICCEP.2015.7177571

Abstract: This paper discuss as the dynamics of a SMPS can be investigated by recurrent neural network (RNN) based models with an Hamiltonian formulation and function used for the training, so leading to a novel paradigm that we call RNNHT model. By using the calculated state variables in a boost converter a RNN is trained by considering also the minimization of the energy stored according to a defined cost function. Simulation results show the improvements in the dynamic performance output prediction versus some well assessed boost converter models in the recent literature.

keywords: {DC-DC power convertors;battery storage plants;learning (artificial intelligence);photovoltaic power systems;power engineering computing;power generation economics;recurrent neural nets;DC-DC boost converter model;Hamiltonian formulation;Hamiltonian-based training algorithm;RNNHT model;SMPS modeling;battery storage systems;calculated state variables;defined cost function;dynamic performance output prediction improvement;energy minimization;neural paradigm;photovoltaic applications;recurrent neural network based models;solar photovoltaic generation system;Computational modeling;Inductors;Integrated circuit modeling;Mathematical model;Switched-mode power supply;Switches;Training;Boost converter;Dynamic modeling;Hamiltonian formulation;Photovoltaic;Recurrent neural network;SMPS;Simulation;Training algorithm},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7177571&isnumber=7177533>

D. Cai, T. Xie, Q. Huang and J. Li, "Short-term solar photovoltaic irradiation predicting using a nonlinear prediction method," *2014 IEEE PES General Meeting | Conference & Exposition*, National Harbor, MD, 2014, pp. 1-5.

doi: 10.1109/PESGM.2014.6939406

Abstract: The power output of grid-connected solar photovoltaic (PV) is intermittent due to the influences of solar irradiance which makes the PV system unreliable especially in the condition of high penetration rates of PV. Forecasting the solar irradiance and power output of a PV plant is an effective way to solve the problem. The proposed method utilizes a tracking camera to capture the stochastic clouds near the sun. The predicting of PV power is achieved in two stages: in the first stage a

series of image processing methods are used for calculating the motion of clouds and in the second stage a nonlinear predicting method is used for predicting the possible path of clouds and arrival time of clouds shading the PV system. The results show the effectiveness of the integrated method.

keywords: {cameras;image processing;photovoltaic power systems;solar power;cloud motion;clouds shading;grid connected solar photovoltaic;nonlinear prediction method;short term solar photovoltaic irradiation prediction;solar irradiance forecasting;stochastic clouds;tracking camera;Cameras;Clouds;Forecasting;Photovoltaic systems;Radiation effects;Sun;Markov Chain;PV;image process;nonlinear function;short-term prediction},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6939406&isnumber=6938773>

S. Basterrech, L. Zjavka, L. Prokop and S. Mišák, "Irradiance prediction using Echo State Queueing Networks and Differential polynomial Neural Networks," *2013 13th International Conference on Intelligent Systems Design and Applications*, Bangi, 2013, pp. 271-276.

doi: 10.1109/ISDA.2013.6920748

Abstract: This paper investigates the estimation of a real time-series benchmark: the solar irradiance forecasting. The global solar irradiance is an important variable in the production of renewable energy sources. These variable is very unstable and hard to be predicted. For the prediction, we use two new models for time-series modeling: Echo State Queueing Networks and Differential polynomial Neural Networks. Both tools have been proven to be efficient for forecasting and time-series modeling. We compare their performances for this particular data set.

keywords: {estimation theory;neural nets;photovoltaic power systems;polynomials;power engineering computing;queueing theory;renewable energy sources;time series;PV power plant;differential polynomial neural networks;echo state queueing networks;renewable energy sources;solar irradiance prediction;time-series benchmark estimation;Artificial neural networks;Atmospheric measurements;Gain measurement;Gold;Particle measurements;Polynomials;Differential Polynomial Neural Networks;Echo State Queueing Networks;Irradiance prediction;Renewable energy;Time-series modeling},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6920748&isnumber=6920429>

D. Lee, "Short-term prediction of wind farm output using the recurrent quadratic volterra model," *2011 IEEE Power and Energy Society General Meeting*, San Diego, CA, 2011, pp. 1-8.

doi: 10.1109/PES.2011.6039128

Abstract: This paper presents a way to use the recurrent quadratic Volterra system to forecast the wind power output. The recurrent quadratic Volterra system is a second-order polynomial equation that uses the output data as feedback recursively. The Volterra system is extracted from the weights of the Recurrent Neural Network. During this process, three innovative techniques are used. In order to make Volterra kernels from the combination of weights, the activation function is approximated to the high-order polynomial function by using the Lagrangian interpolation. Furthermore, the memory of the Volterra system is also identified using the Partial Autocorrelation Function. After building the Volterra system, the 15 and 30-minutes ahead of wind power output is forecasted with confidence intervals at the 95% confidence level. The confidence interval is calculated using the multi-linear regression techniques. The stability of the recurrent Volterra system is also considered by the heuristic method.

keywords: {Volterra equations;interpolation;load forecasting;polynomials;recurrent neural nets;regression analysis;wind power plants;Lagrangian interpolation;Volterra kernels;activation function;feedback;high-order polynomial function;innovative techniques;multilinear regression technique;partial autocorrelation function;recurrent Volterra system stability;recurrent neural network;recurrent quadratic Volterra model;second-order polynomial equation;short-term prediction;wind farm output forecasting;Forecasting;Kernel;Neurons;Polynomials;Predictive models;Wind forecasting;Wind power generation;Recurrent Neural Network;Short-Term Forecasting;Volterra system;Wind Power System},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6039128&isnumber=6038815>

N. Hamrouni, M. Jraid, A. Cherif and A. Dhouib, "Measurements and Simulation of a PV Pumping Systems Parameters Using MPPT and PWM Control Strategies," *MELECON 2006 - 2006 IEEE Mediterranean Electrotechnical Conference*, Malaga, 2006, pp. 885-888.

doi: 10.1109/MELCON.2006.1653240

Abstract: In this paper, we will introduce a new strategy of modeling and control of photovoltaic pumping systems under MATLAB/SIMULINK environment. This approach is based on the dynamic model of the "PV-MPPT adapter-inverter-asynchronous motor-pump". The MPPT control allows the extraction of the maximum output power delivered by the PV generator. However the inverter insures a PWM control of the asynchronous motor and a sine wave form of output signals. This methodology allows an optimal control and monitoring of continuous-continuous and continuous-alternative inverters by calculating the cyclic ratio of the DC-DC converter and the voltage/frequency (V/f) control law of the DC-DC inverter. This method leads to a best prediction of the behavior and performances of the photovoltaic plant especially in the case of climatic and load fluctuations

keywords: {DC-DC power convertors;PWM invertors;frequency control;induction motors;optimal control;photovoltaic power systems;power generation control;voltage control;DC-DC converter;MATLAB;PV generator;PV pumping systems parameters;PWM control strategies;SIMULINK;asynchronous motor;continuous-alternative inverters;optimal

control;photovoltaic plant;photovoltaic pumping systems;voltage/frequency control;MATLAB;Mathematical model;Monitoring;Optimal control;Photovoltaic systems;Power generation;Power system modeling;Pulse width modulation;Pulse width modulation inverters;Solar power generation},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1653240&isnumber=34649>

D. R. Burger, R. L. Mueller, G. Goodelle, J. Powe and J. Schwartz, "Angle of incidence corrections for GaAs/Ge solar cells with low absorptance coverglass," *Conference Record of the Twenty Fifth IEEE Photovoltaic Specialists Conference - 1996*, Washington, DC, 1996, pp. 243-246.

doi: 10.1109/PVSC.1996.563992

Abstract: A total of four different types of coverglass/filter combinations were tested over a 0 to 85 degree angle of incidence range. One group of cells was irradiated to provide additional data. A predicted cell response was calculated using the cosine and Fresnel corrections. A comparison of measured versus predicted values showed a good fit for blue reflection or anti-reflection (AR) filters. Both blue-red and infrared reflection filtered cells showed decreased output in the 40 to 80 degree range due to movement of filter IR band-edge into cell response range. Performance at very high incidence angles is still not fully understood. A special infrared filter was used which did not have an angle of incidence effect. Irradiation of cells improved angle of incidence performance for cells with infrared reflection filters

keywords: {III-V semiconductors;aerospace simulation;elemental semiconductors;gallium arsenide;germanium;optical filters;photovoltaic power systems;semiconductor device models;solar cells;space vehicle power plants;Fresnel correction;GaAs-Ge;GaAs-Ge solar cells;angle of incidence corrections;anti-reflection filter;blue reflection filter;cell response prediction;cosine correction;coverglass;incidence angle;incidence performance;infrared reflection filter;space power;Fresnel reflection;Gallium arsenide;Laboratories;Optical filters;Optical reflection;Optical refraction;Optical surface waves;Photovoltaic cells;Space technology;Space vehicles},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=563992&isnumber=12206>

G. P. Summers *et al.*, "A new approach to damage prediction for solar cells exposed to different radiations," *Proceedings of 1994 IEEE 1st World Conference on Photovoltaic Energy Conversion - WCPEC (A Joint Conference of PVSC, PVSEC and PSEC)*, Waikoloa, HI, 1994, pp. 2068-2075 vol.2.

doi: 10.1109/WCPEC.1994.521828

Abstract: Accurate prediction of solar cell performance in a space radiation environment is essential for selecting the appropriate cell technology for a given mission. A methodology for carrying out such assessments based on experimentally determined cell degradation as a function of electron and proton fluence has been applied successfully for many years. The necessary data to apply this methodology to novel cell types is usually not available, however, and it is imperative to be able to extract the maximum possible information from limited data. In this paper a new approach is outlined based on damage correlation using "displacement damage dose" which is derived from the product of the calculated nonionizing energy loss and the fluence. For electron damage it is found necessary in some cases to define a quantity "1 MeV electron equivalent dose" from which 1 MeV electron equivalent fluence can be calculated. With this new approach to damage correlation, it is possible to make accurate predictions of the expected degradation of solar cell performance in complex space radiation environments based on measurements made with only one proton energy and two electron energies, or with one proton and electron energy, and Co^{60} gammas. The power of the method is demonstrated using reported data for GaAs and Si cells

keywords: {III-V semiconductors;elemental semiconductors;gallium arsenide;photovoltaic power systems;radiation effects;semiconductor materials;silicon;solar cells;space vehicle power plants;1 MeV;GaAs;GaAs cells;Si;Si cells;displacement damage dose;electron damage;electron energy;electron equivalent dose;electron fluence;nonionizing energy loss;proton energy;proton fluence;radiation damage prediction;solar cell performance;solar cells;space radiation environment;space radiation environments;Appropriate technology;Data mining;Degradation;Electrons;Energy loss;Extraterrestrial measurements;Photovoltaic cells;Protons;Space missions;Space technology},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=521828&isnumber=11459>

P. P. Jenkins, D. A. Scheiman, D. J. Brinker and J. Appelbaum, "Low intensity low temperature (LILT) measurements and coefficients on new photovoltaic structures," *Conference Record of the Twenty Fifth IEEE Photovoltaic Specialists Conference - 1996*, Washington, DC, 1996, pp. 317-320.

doi: 10.1109/PVSC.1996.564009

Abstract: As RTGs have become increasingly less desirable for outer-planetary missions, solar cell performance data at very low temperatures and intensities are required. The authors have measured low intensity, low temperature (LILT) I-V data on single junction and multi-junction high efficiency solar cells, representing the state-of-the-art in photovoltaic technology. Using this LILT data to calculate I_{sc} , V_{oc} , and FF as a function of temperature and intensity, an accurate prediction of cell performance under the AMO spectrum can be determined. When combined with quantum efficiency at low temperature (QULT) data, one can further enhance the prediction by the addition of spectral variation. This paper presents an overview of LILT measurements taken at temperatures as low as -180°C and intensities ranging from 1 Sun to 0.02 Suns. The temperature dependency coefficients presented in this paper are experimental results intended to provide a guideline for array design

keywords: {aerospace testing;cryogenic electronics;electric current measurement;photovoltaic power systems;semiconductor

device testing;solar cell arrays;solar cells;space vehicle power plants;thermal analysis;voltage measurement;I-V data;LILT studies;fill factor;low intensity low temperature measurements;open-circuit voltage;photovoltaic technology;quantum efficiency;short-circuit current;solar cell array design;solar cell performance data;space power solar cells;spectral variation;state-of-the-art;temperature dependency coefficients;Extraterrestrial measurements;Gallium arsenide;Indium phosphide;Photonic band gap;Photovoltaic cells;Photovoltaic systems;Planets;Solar power generation;Sun;Temperature measurement},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=564009&isnumber=12206>

M. J. Mackowski and D. K. Martin, "An energy balance simulation tool for TOMS-EP," *IECEC 96. Proceedings of the 31st Intersociety Energy Conversion Engineering Conference*, Washington, DC, 1996, pp. 641-646 vol.1.

doi: 10.1109/IECEC.1996.552968

Abstract: A computer analysis tool has been developed to perform energy balance simulations of a spacecraft power subsystem. The purpose of the program is to predict the battery state-of-charge (SOC) as a function of time for different scenarios for the first few orbits of the Total Ozone Mapping Spectrometer-Earth Probe (TOMS-EP) satellite. The satellite proceeds from boot-up while tumbling, through deployment and attitude stabilization via a combination of ground commanded and autonomous events during this period. The model calculates the battery state-of-charge profile, based on initial input conditions and variable load profiles (power use versus time). This model has the capability to reflect changes in the power generated by the solar array, which varies as the simulation progresses. Using this process, which includes an ability to define the events that trigger changes in the loads or solar array output power, many different operational scenarios can be modeled. This tool has been used to evaluate responses to various failure modes and contingencies for the first few orbits of the TOMS EP mission

keywords: {aerospace simulation;artificial satellites;photovoltaic power systems;secondary cells;solar cell arrays;solar cells;space vehicle power plants;TOMS-EP;battery state-of-charge prediction;energy balance simulation tool;failure modes;load profiles;operational scenarios;satellite power system;solar array;space power;spacecraft power subsystem;Analytical models;Batteries;Computational modeling;Computer simulation;Orbits;Performance analysis;Power generation;Satellites;Space vehicles;Spectroscopy},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=552968&isnumber=11973>

J. G. Severns, R. W. Conway, B. J. Faraday and R. M. Hobbs, "Flight experience with LIPS-III," *Proceedings of the 24th Intersociety Energy Conversion Engineering Conference*, Washington, DC, 1989, pp. 399-404 vol.1.

doi: 10.1109/IECEC.1989.74493

Abstract: The Satellite LIPS III, the third in the series of living plume shield spacecraft, was launched into a low Earth orbit late in the spring of 1987. Some 140 solar cell experiments were placed on LIPS, and data from these has been acquired for two years. The quality of the current-voltage characteristic measurements is reviewed, and some anomalies in the data are described. In particular, excursions of measured short-circuit current which well exceed experimental error, are described. A model is proposed for prediction of Earth solar reflectance, and correlation between the calculated reflectance and excursions of short-circuit current is shown graphically. It is concluded that these excursions are of solar origin and not caused by a malfunction of the spacecraft

keywords: {solar cells;space vehicle power plants;Earth solar reflectance;LIPS III;Satellite;current-voltage characteristic measurements;living plume shield spacecraft;low Earth orbit;short-circuit current;solar cell experiments;Current measurement;Current-voltage characteristics;Extraterrestrial measurements;Lips;Low earth orbit satellites;Particle measurements;Photovoltaic cells;Reflectivity;Space vehicles;Springs},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=74493&isnumber=2490>

G. F. J. Garlick and B. S. Smith, "Improved prediction and analysis of cell performance at elevated temperatures," *Conference Record of the Twentieth IEEE Photovoltaic Specialists Conference*, Las Vegas, NV, USA, 1988, pp. 587-590 vol.1.

doi: 10.1109/PVSC.1988.105769

Abstract: Improved modeling and analysis have been applied to data on Si solar cells made for the Magellan satellite (Venus orbits) at temperatures from -50 to 100 degrees C. Derived saturation currents for the cells have been used to calculate base minority carrier lifetimes. These rise with temperature, showing some saturation near 100 degrees C. Data are quantitatively explained by an energy band model with divacancy levels at 0.25 eV and impurity levels at 0.6 eV above the valance band. Close fits to experimental results are found for concentrations of $6 \times 10^{12}/\text{cm}^3$ and $1.5 \times 10^{11}/\text{cm}^3$ for the 0.25 and 0.6 eV levels, respectively. At 100 degrees C the saturation is controlled by the latter, while divacancies affect the lifetimes at lower temperatures. It is concluded that this analysis of quite usual test data for cells, coupled with temperature variation, provides a powerful insight into basic parameters which determine the cell operational performance.<>

keywords: {carrier lifetime;elemental semiconductors;energy gap;impurity electron states;minority carriers;silicon;solar cells;space vehicle power plants;-50 to 100 degC;Magellan satellite;Si solar cells;Venus orbits;base minority carrier lifetimes;divacancy levels;energy band model;impurity levels;performance analysis;saturation currents;semiconductor;valance band;Charge carrier lifetime;Impurities;Orbital calculations;Orbits;Performance

analysis;Photovoltaic cells;Satellites;Temperature control;Testing;Venus},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=105769&isnumber=3239>