

Review on Different Solar Energy Prediction Modeling Techniques Based on Complexity, Performance time and Accuracy

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Abstract

During the past few years, the demands for clean and sustainable sources of energy have been increased significantly mostly. Thus nowadays clean sources of energy like solar energy consider as one of the best and important solutions. Fossil fuel is considered as non-renewable sources of energy. This sort of source could be over at any time, and this is one of the main important reasons that has made most industrial countries start to recognise the need for clean sources of energy. The Sun radiation information gives data on what amount is the sun potential at an area in the world for a specific time at the particular day. This information is fundamental for outlining and estimating based on mathematical and processing techniques. Because of the high financial cost and wasted time for the amount of potential sunlight estimation, these data are not available everywhere at any time. Consequently, there is a request to employ elective methods for sun-powered energy information foreseeing. By fixing the goal as arranging an alternate resource of information that substitutes the missed data globally or zones wise. Eventually, different arrangements have been proposed in this regard. For example, the collected solar energy facts can be utilized for creating Predictive solar Model which portrays the numerical relations between the solar radiation and the meteorological factors like temperature, cloud cover and daylight proportion. This paper exhibits a review and assessment of various strategies of solar energy utilisation. Slight procedures like Linear Model (LM), Nonlinear Model (NLM), Multiple Linear Regressions Model (MLRM), Artificial Neural Network Model (ANNM), Fuzzy Logic Model (FLM), Adaptive Neuro-Fuzzy Inference Mode (ANFLM) and Particle Swarm Optimization Mode (PSOM) were discussed. Such anticipated information in light of mean

supreme rate blunder. The outcomes demonstrated that ANN model is an unrivalled correlation with different models.

Keywords: Solar Energy; Solar radiation, Predictive Model, LM, NLM, MLRM, ANNM, FLM, PSOM, ANFLM

INTRODUCTION

Rapped changing in the global climate for the time being based on pollution, and exponential growth of energy consumption caused by technology expansion, the consumption of the non-renewable energy (fuel stocks), are being utilized at a tremendous and unsustainable rate. These assets will vanish sooner or later not long from now. Like this circumstance constrains us to seek for better liveliness clean sources, which makes the renewable energy the available choices for all mentioned problems above [1,] [2]. These issues empower the examination of utilising sun oriented, wind, hydropower, biogas, geothermal vitality and other renewable energies for the era of electrical power [3]. Sun based energy is the richest wellspring of an energy source that has direct and indirect massive effect on earth. The sun is by far the oldest energy source which supplied the earth with light and heat for millions of years and is directly responsible for maintaining all forms life on earth planet. It generated a great deal of energy in every second which travels through space as radiations [4]. Sun radiations that converted to electricity with the help of photovoltaic (PV) and sun orientation tracking design along with solar thermal energy based on the temperature which generated by solar power can make impressive commitments to taking care of a portion of the energy issues that confront the world nowadays. PV modules are one of these friendly arrangements which could

be used by change over the sunlight radiation into power utilising semiconducting materials. Furthermore, these modules disband numerous issues particularly in cost, and it might give excellent plan with a high proportion of vitality. Sun based radiation information gives data on what amount is the sun potential at an area on the Earth amid a particular era. This information is essential for outlining and measuring sun based PV frameworks as specified previously. Because of the high cost and establishment challenges of estimation, this information is not accessible. In this manner, there is a request to create elective methods for anticipating this evaluated information [5]. These models can be later used to foresee the immediate and diffuse sun oriented vitality utilising verifiable meteorological information at locales where there is no sun radiation measuring gadget introduced. Solar energy has been mimicked by utilizing different and creative models comprise o linear, nonlinear, ANN, FL, MLR and PSO models. Be that as it may, some checking on work concerning solar energy prediction models can be discovered [6]-[8].

In this way, the majority of the past seeking papers spin on linear, nonlinear and ANN models for solar radiation while different procedures, for example, FL and MLR systems are absent. Along these lines, this paper gives a review over a wide span of time research works identified with the solar radiation modelling strategies.

LITERATURE SURVEY

In the examination field of sun based radiation, expectation models method can be part of two sorts of methodologies or sub-classes, in particular, physical displaying and information demonstrating. From one viewpoint, the physical models for sun based irradiance have as of now been superior to information demonstrating [8]. More lately examines concentrate on discovery demonstrating innovations that depend on the watched sun-powered radiation information straightforwardly. Numerous techniques are utilised to break down the watched sunlight based radiation information, for example, neural systems. Be that as it may, they are predominantly semi observational numerical models, which contain much experience as learning or comparing data. [9], some upgraded nonlinear numerical models are used to portray the physical systems a great deal more precisely. Sadly, the parameters of these models change in various elements, and it is not easily measurable, and that is the models' fundamental boundary. It is scientific models as specified, is not like physical models and simply identifies with the watched sun based radiation information. Then again, the model of solar radiation can likewise be controlled by the watched information. Notwithstanding, the non-linear attributes of the watched sun oriented radiation information have not been offered adequate consideration till now. Sun oriented radiation information is identified with the topographical area, as well as have an association with neighbourhood meteorological components, for example, temperature, water vapour, suspended solids, cloud, and water. Nonetheless, this information demonstrating techniques simply get the input-output relationship and overlook the inner instrument of the watched sun oriented radiation

information. Quickly, some astounding work has been investigated they all constitute an emphatically coupled multi-variable framework, and sunlight based radiation is only a yield variable of this advanced framework.

LINEAR MODELING TECHNIQUE (LM) OF SOLAR RADIATION:

By and large, by utilising linear and nonlinear models, solar energy models were created before. These models give a connection between solar radiation on a flat surface and some meteorological factors, for example, sunlight hours, surrounding temperature and other relevant parameters. The linear models utilised linear capacity; the nonlinear models, on the other hand, utilise the polynomial capacity of the 3rd or 4th degree [10]. The connection between diffuse solar energy E_d and global solar energy E_t (E_d/E_t), concerning the clearness index K_t which equivalent to $E_t/Extra$ is known as a linear model, where the Extra Extraterrestrial solar energy that struck the earth above the ionosphere level. A linear model universal condition that computes the diffuse energy and it is taken in the next formula

$$E_d/E_t = a + bK_t$$

Where, a and b are the model coefficients.

The accompanying direct expression is utilised for information got from ten meteorological stations situated in the vicinity of 40°N and 40°S scopes [7],

$$E_d/E_t = 1.0 + 1.13K_t$$

Tuller [8] considered information from four actinometrical stations of Canada and proposed the accompanying expression:

$$E_d/E_t = 0.84 + 0.62K_t$$

For scopes under 50°, the Tuller condition can suggest while for scores more than 50°, the Iqbal condition [5] is more reasonable. Given the information from southern Canadian stations, the same direct condition with limitations on K_t is utilised as takes after:

$$E_d/E_t = 0.84 + 0.62K_t \quad (0.34 < K_t < 0.6)$$

Notwithstanding, in light of the 12 meteorological stations from India, Modi et al. [9] built up a relapse condition:

$$E_d/E_t = 1.4112 + 1.6956K_t \quad (0.34 < K_t < 0.73)$$

Table 1. The linear model's coefficients.

Station	a	b
Turkey	1	1.13
Canada	0.84	0.62
India	1.4112	1.6956
Malaysia	1.2623	-1.3307
Thailand	0.753	-0.039
Indonesia	1.557	-1.84

Table 2. Linear model coefficients for different meteorological stations in Malaysia

Station	Alor Setar	Ipoh	Johor Bharu	Kuala Lumpur	Kuching	Average
Coefficients a	1.2602	1.2867	1.2407	1.2841	1.2398	1.2623
Coefficients b	-1.3265	-1.3771	-1.2882	-1.3765	-1.2848	-1.3307

By utilising the normal coefficients values in Table 2, a linear model for diffuse solar energy in Malaysia is determined in [11] $E_d/E_t = 1.2623 - 1.3307K_t$.

Table 2 the linear model's coefficients for different meteorological stations in Malaysia

Nonlinear Modelling Technique (NLM)

For nonlinear procedure the general model condition is $E_d/E_t = a + bK_t + cK_t^2 + dK_t^3$. Kenisarin et al [12] utilised 34 sets of USSR meteorological station information for setting up such a relationship by utilising the 12 every day estimations of E_d/E_t and K_t . A nonlinear of the third order polynomial model had taken into consideration for the nonlinear model. Lui and Jordan [13] likewise built up a connection between E_d/E_t and K_t . Moreover, with five arrangements of actinometrical station information from the USA, Collar et al [14] recommended and condition whose coefficient changes with the seasons. The model's coefficients appear in Table 3.

Table 3. Third order polynomial nonlinear models coefficients for global meteorological Stations

Station	a	b	c	d
Malaysia	0.9497	0.927	-4.8821	3.2542
Indonesia	1.0045	0.04349	-3.5227	2.6313
China (Chengdu)	1.0856	-3.5199	6.3831	-3.1693
China (Geer)	-5.4207	21.5134	-25.7234	10.5658
China 86 station	0.15	1.145	-1.474	0.963
China 69 station	0.1275	0.725	-0.2299	0.1837
USSR	1.191	1.783	0.862	0.324
USA	1.39	4.027	5.531	3.108
USA	1.391	3.506	4.189	-2.137
USA	1.311	3.022	3.427	1.821
Malaysia	0.9497	0.927	-4.8821	3.2542
Gordon	1.0278	-1.9039	2.362	-1.7527
Morocco	-0.759	5.869	-8.8847	3.59
USA	1.391	-3.56	4.189	-2.14
Oregon	0.916	1.248	-5.551	3.215
INDONESIA (hourly)	1.0045	0.04349	-3.5227	2.6313
INDONESIA (monthly)	1.390	-4.027	5.531	-3.108

Subsequently, a prescribed nonlinear model for the diffuse solar energy in Malaysia is determined by utilising the average coefficient estimations of Table4 as shown in this model [1]. $E_d/E_t = 0.9497 + 0.927K_t - 4.8821K_t^2 + 3.254K_t^3$

Table 4. The nonlinear model's coefficients for different meteorological stations in Malaysia

Station	Alor Setar	Ipoh	Johor Bharu	Kuala Lumpur	Kuching	Average
Coefficients a	0.9540	0.9503	0.9522	0.9434	0.9486	0.9497
Coefficients b	0.8834	0.9314	0.8799	0.9895	0.9507	0.9270
Coefficients c	-4.7559	-4.8726	-4.6988	-5.0309	-5.0524	-4.8821
Coefficients d	3.1623	3.1623	3.0503	3.3477	3.4974	3.2542

Multiple Linear Regressions Modeling Technique (MLRM)

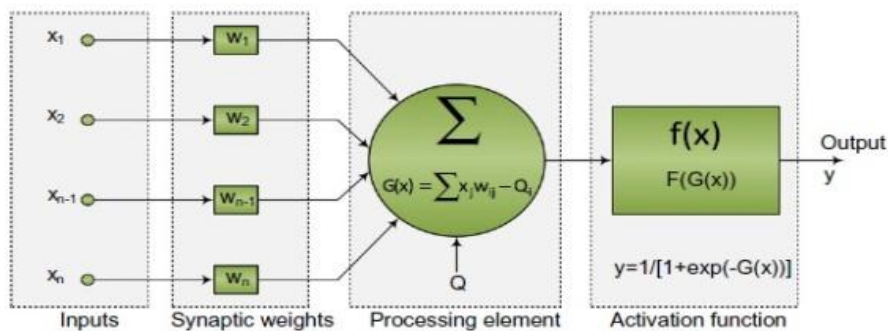


Figure 1. MLR Architecture

Recognized as random impacts models, combining between linear and this model, is a set of variation for more than one analytical technique level and a mathematical agent which utilised to serve multipurpose, all together with the analysis the variations that may occur during processing [15]. Regressions modelling utilised to represent the connection between one ceaseless ward variable from at least two independent factors. The examination of MLR is a measurable way that review cause-impact connections amongst needy and autonomous factors as specified some time recently. In MLR, the connection between info variable more than one (x_1, x_2, \dots, x_n) and a needy variable (y) is inspected. In any case, the relapse work that will be utilised here is characterised as taking after $y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n$. Where it is acknowledged that every free factor has a straight association with a needy variable. MLR investigations can be communicated with the accompanying numerical expression: $Y = a_0 + a_1 X_1 + a_2 X_2 + \dots + a_n X_n + \epsilon$. Where Y indicates the reliant variable, a_i are the relapse coefficients, X_i are the autonomous factors and ϵ indicates stochastic mistake of the relapse. A wide assortment of techniques has been displayed to the variable determination issue. The issue of deciding the best subset of indicator factors in various straight relapses has been enthusiasm for quite a while and keeps on getting significant consideration. Along these lines, it is imperative to

consider every conceivable condition to discover the best indicator factors. There are techniques which have the component that the factors are introduced or erased from the condition each one in turn, and include looking at just a subset of every single conceivable condition.

Artificial Neural Network Modeling Technique (ANNM)

An ANN was taken from the basic Anatomy concept of an organic neural framework, made out of layers of basic parallel units called neurones. The neurones are associated with a substantial number of weighted connections, over which signs or data can pass. A neurone gets contributions from its approaching associations, joins the data sources, by and large plays out a non-straight operation and yields the last outcomes. ANN relied on feed forward multilayer perception (FFMLP) through the often utilised neural networks that learn from previous data.

ANNs are data treatment, and development methods that are non-digital or algorithmic are intensely going alongside. Fig. 2 showed a schematic description of the basic architecture. It has consisted of three zones: the input, hidden and output layers. Association qualities named weights interconnect each layer. Four geological and climatic factors were utilised as info parameters for the information hubs of the info layer.

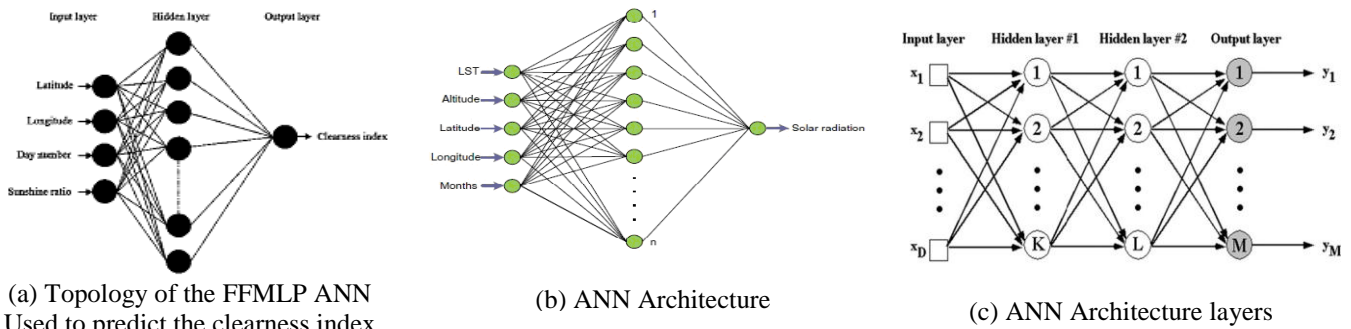


Figure 2. Artificial Neural Network

These factors were the day number, latitude, longitude and daily sunshine hour's ratio. A single hub or neurone was at the yielding layer with the evaluated day by day clearness list expectation as the yield. The exchange work received for the neurones was a strategic sigmoid capacity $f(Z_i) = 1 / (1 + e^{-Z_i})$, $Z_i = \sigma_1 w_{ij} x_j + \beta_i$. Where Z_i is the weighted entirety of the sources of info, x_j is the approaching signal from the j^{th} (at the information layer), w_{ij} the weight on the connection directed from neuron j to neuron i (at the hidden layer) and β_i the bias of neuron i .

Fuzzy Logic Modelling Technique (FLM)

This theory has been presented by Zadeh (1965) [16], and it means using the fractions real numbers that situated between 0 and 1. In between these two limits, intermediate values can be

allowed. It is similar to the way that how the human think, how to make decisions and good solutions from rough data. From the time of the concept of logic by Aristotle that stated, it is either true or false that every motion of suggestion must be, except medium of them. On the other hand, under the similar concept of grey, fuzzy logic is created to permit computers to make use of the disparities between data. The idea makes the membership function (or the values False and True) work over the variety of real numbers (0, 1). At the same time, misperception should not occur between the concept of truth degree that used in fuzzy theory and probabilities; they are theoretically dissimilar. Boolean logic can be understood as a subsection of fuzzy logic.

In this theory, the user describes physical characteristics to supplied linguistic variables as linguistic values; no numbers were involved, called attributes. Words or phrases represent it. The definition of a fuzzy set is $A = \{(x, m_A(x)): x \in X\}$.

The membership function $m_A(x)$ is linked to each attribute and characterizes the linguistic variable, by signifying the degree of which the attribute is. Application defines the form of membership functions and the number of attributes of a linguistic variable. In standard set theory, also named crisp sets, a membership function $m_A(x)$ equals 1, if $x \in A$, or 0, otherwise. In general, the characteristic function $0 \leq m_A(x) \leq 1$ which is direct the degree of originality of an element x to a fuzzy set A .

Three types of Fuzzy models are available, the Mamdani–Larsen (ML), Takagi–Sugeno (TS) and generalised fuzzy model GFM [17]. An accurate depiction of the fluffy sets and fluffy rationale usage for sunlight based vitality estimation can be found in [5, 14]. In the fluffy rationale usage, the sun oriented vitality factors which are daylight length, and solar energy are portrayed as far as phonetic factors, for example, long, high, shorten etc.

Adaptive Neuro-Fuzzy Logic Modeling Technique (ANFLM)

This modelling was initially given by Jang [18] and later on broadly practised in different problems. It is a combination of an FL and ANN models. ANFLM has the capacity of handling any real persistent function on a concise series of parameters to any degree of precision [19]. The inputs parameters for the fuzzy inference system come from the output resolute of the neural network learning algorithms will be input parameters for the fuzzy inference system. ANFLM classifies a set of parameters through a dually learning rule combining a least squared error method and back-propagation gradient descent error digestion. Two methods for fuzzy inference are available, which are Mamdani [20] and Sugeno [21] approaches. However, there is a distinction between them (the two methods) namely, in Sugeno's method utilises linear or constant functions while Mamdani's approach utilizes fuzzy membership function.

Particle Swarm Optimization Modeling Technique (PSOM)

Kennedy and Eberhart introduced PSO in (1995) [22]. The conduct of winged animal rushing, bug swarming, and angle swimming was the motivation for this technique. In a particular hunt space, PSO relies on upon various people (particles) changing their position. Every molecule is sorted by its station and signifies easy answer for the issue. The development of every molecule goes in various headings look to space, with a specific end goal to find higher wellness positions. From the underlying arbitrary populace of particles, PSO begins, where every molecule is a hopeful arrangement. Speed and position for every molecule are haphazardly instated. Every molecule learns (spare) its own best position that at any point confronted amid the procedure of enhancement which is named the neighbourhood best, in the meantime, the best position for all individual will be

remembered by the populace and named as the worldwide best. Inactivity weight is exhibited for dealing with the harmony between the worldwide and nearby examination abilities of the particles. Through the enhancement procedure, the inactivity weight is directly diminished to affirm the pursuit all around at first cycles and locally with conclusive emphasis. PSO has a greater number of points of interest than other streamlining procedures like: straightforward in the idea, simple to execute, and computationally effective.

SUMMARY

Modelling techniques for solar energy prediction in general, are used to provide information on how to get solar energy to the earth's surface for specific location during a certain period. Solar energy for a specific location is useful to investment or not, without the necessity of the presence in that specific location, for this reason, it is very important to get the closest and best estimate, so to match with the real data. There is a pressing requirement for this information for the powerful hunt to utilise this sun-powered vitality and this is because of high cost and the trouble of discovering sun based radiation estimations. In any case, this information is not promptly accessible. Hence, unique option techniques are required for produced this information. In this paper, an audit is made of the solar energy demonstrating methods use for this reason, yet the most prevalent models are incorporated that the mentioned above which has compared with each other by considering the major attributes of the modelling techniques.

As blow table (5) shown, the accuracy of modelling techniques is divided into three categories which are (High, low, fair) and for time consumption as (Fast, long, fair). In addition to the category of complexity as (High, low, fair).

Comparing between the mentioned models has been made, based on the previous classification which depends on the nature of the modelling technique. ANN has a better result than Multiple Linear Regression through MBE and RMSE values. "It is seen that the ANN model is more effective than MLR for assessing SR" [35]. Moreover, beside the uses limitation in solar radiation by fuzzy logic and Adaptive Neuro-Fuzzy Inference Models, besides the complexity also available compared with the selected models, hence these models has dropped from selecting. PSO model is simple and easy to implement [36], though it is not commonly applied to the chosen models. By taking the consideration of the previous information, the final selection was on linear, nonlinear and ANN modelling techniques based on the commonly used, simplicity with the accepted accuracy especially for the models linear and nonlinear on another hand for the best modelling technique regarding accuracy is ANN. The third chapter will concentrate on the linear and nonlinear techniques, hence to propose a linear and nonlinear model for South East Asia region. Meanwhile, these models are compared with a global model and other country models which belong to the same rejoin.

Table 5. Types of modelling techniques and their accuracy, time, and complexity in different locations.

Modelling Technique	Accuracy	Time Consumption	Complexity	Country Use	References
LM	Low	Fast	low	Between 40°N and 40°S, Malaysia, Canada, India, Turkey, Indonesia etc..	[23-27]
NLM	Fair	Fast	low	Malaysia, UAS, Jordan, Morocco, China, Indonesia, Oregon, etc.	[6,28-31]
MLRM	Fair	Long	High	USA, Turkey, India, etc.	[32]
ANNM	High	Long	High	UK, USA, Turkey, India, Malaysia, etc.	[22,23,33]
FLM	High	Long	High	Spain, India, Romania, Turkey, etc.	[16,34,19]
ANFLM	High	Long	High	USA, Spain, India, etc.	[18]
PSOM	Fair	Fair	Fair	Iran, Saudi Arabia, China, India, etc.	[22]

CONCLUSIONS

This review has indicated diverse systems for Solar Energy Prediction Models as said beneath which rely on upon different parameters like, quality, execution time and precision. Nonlinear is a basic framework which requires more info parameters and time to forecast. It simply needs the base info parameters to portray the data of the qualities of the building components and the climatic conditions. Like nonlinear framework, HLM is the additionally straightforward way that can be a relevant estimation of numerous contributions over a day and age. Notwithstanding, MLR is a relapse method that used to get connection amongst reliant and free factors. It permits multi contributions at the time. The Fuzzy rationale was additionally connected to anticipating sun based vitality where there are ambiguities and unclearness in sunlight based vitality and daylight span records in a day. The principal preferred standpoint of the fluffy rationale model is that it can be conceived for taking care of instabilities in assessing the sunlight based radiation. At last, ANN is appropriate for linear and nonlinear conditions, particularly for complex issues it is more precise and speedier than different methods for expectation and does not require any earlier information about yield. As it comprises of shrouded layers and non-linearity of actuation capacity, their weights are not interpretable.

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