Development of Mathematical Models for Solar Radiation in Palestine

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COMMITTEE DECISION

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DEDICATION

I dedicate this thesis to my wonderful parents, my sisters and brother, my fiance and my friends for their love, unfailing support and continuous encouragement throughout my life.

To everyone who inspires me by his/her science.

Acknowledgment

After thanking Allah, who granted me the ability to finish this work, I would like to express my sincere gratitude to my thesis supervisors: Prof. Dr. Saed Mallak for all his guidance, understanding, support and sound advice in all aspects of my research work and Prof. Dr. Samer Alsadi for his scientific support, encouragement, guidance and constructive advice. and Mr. Hadi khalilia for his helping. I appreciate help and support from members of the Mathematical Department at Palestine Technical University –Kadoorie.

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Contents

in the figure that Markov Chain is the best prediction method (it's very closed from the real).

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AP: Angstorm Prescott	
SA: Simulated Annealing	
PSO: Particle Swarm Optimization	
MS: Markov Chains	

Abstract:

In this thesis, we investigate several methods for the prediction of solar energy in the city of Tulkarm-Palestine. These methods include linear method, nonlinear methods, and Markov chains method. Markov chains method has been implemented using Matlab, MS Excel program and manual application.

Numerical results indicate the accuracy of these methods. However, according to comparison of these methods, we conclude that the Markov chains method provides more optimal result.

في هذه الأطروحة تعاملنا مع عدة طرق في التنبؤ. حيث قمنا بدراسة هذه الطرق وتطبيقها للتنبؤ بالطاقة الشمسية في مدينه طولكرم في فلسطين, ومن الطرق التي تناولنها في دراستنا الطريقة الخطية والطريقة الغير خطيه وطريقه سلاسل ماركوف باستخدام برنامج ماتلاب وبرنامج اكسل وتطبيق يدوي وفي الختام توصلنا إلى أن طريقه سلاسل ماركوف هي أفضل طريقه للتنبؤ بالطاقة الشمسية.

Chapter One
Introduction

1.1 Motivation

Solar energy is a part of the sun's strength that falls on the earth's floor. This energy is to be used for plenty of applications, [12] for raising water's temperature or moving electrons in a photovoltaic cell. Moreover, it gives energy to natural processes like photosynthesis. Solar power is clean, secure and available on the earth all through the year. Such clean energy could be very important to the sector, in particular in the time of high fossil gasoline expenses and the critical situation of pollution of the atmosphere resulting from fossil fuel consumption. The solar energy data provides information on how much is the sun potential at a location on the earth during a specific period. This information is very critical for designing and sizing solar energy systems. Due to the high value and installation difficulties in solar measurement, solar energy facts aren't usually available. Therefore, there may be a call to expand opportunity ways of predicting sun power information.

Nowadays, all studies from past to now are focusing on renewable energy the solar is considered the most important one, energy so we have solar radiation data for a year every hour in a day then we divided the data for a year into seasons to have clear behavior figures and applied several

methods to analyze in this data to reach the best method in predicting solar radiation, now we can predict the solar radiation for many years in future this can help us to have the most benefits from the sun (solar radiation) as we know God blessed our region(Palestine) with high number of hours that the sun shining all the year, the every year average daily solar radiation on the horizontal surface between [5.5-6] kilo watt hour/m^2 and the entire annual sunshine hours exceeds 3000hours [10] and we trying to exploit this blessing to maximizing power and minimizing cost.

Today's world is faced with growing population and energy consumption, which gives rise to extra-large usage of fossil fuels, where energy saving constantly has been one of the important factors of economic growth and development. This led to the emergence of the global warming phenomenon; as a result, the excessive use of fossil fuels has now emerged as a pressing international hassle. Hence, the researchers introduced an idea for using renewable energy as a solution for tackling those fundamental issues. At present most countries have adopted plans for minimizing using fossil fuels and maximizing using renewable energy, this what we see in many applications around the world such that using solar energy (what we adopted in our thesis).

All the research now has shown steady growth in using renewable energy around the word. And a number of those studies trending to predict

renewable energy, figure 1.1 shows that the consumption of renewable energy is increasing (green light) along the time, where the consumption of fossil fuels is decreasing [28].
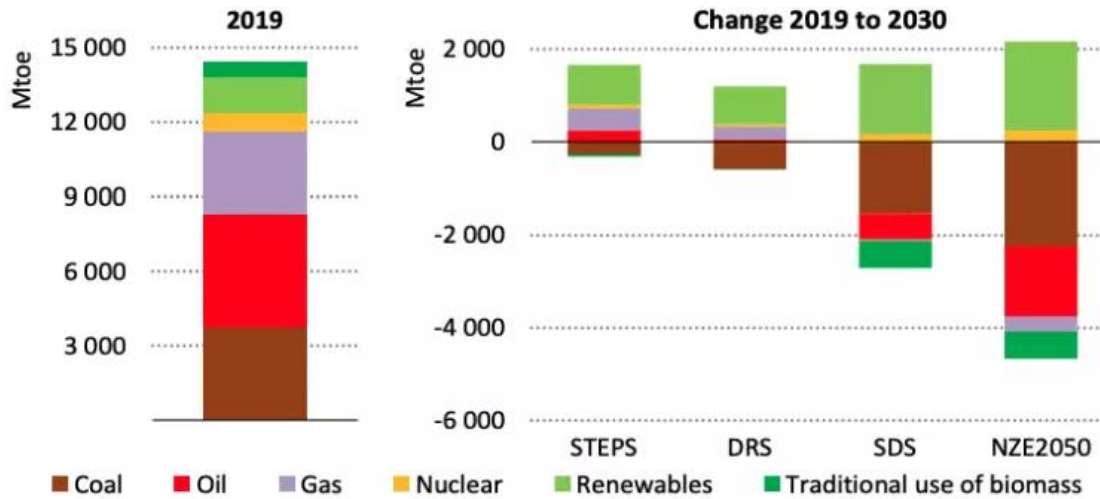
Figure 1.1: Consumption of renewable energy

For the importance of solar radiation on all the world, [29] this makes all researchers focus are on it, and all scientists try to minimize the cost, In 2006 the average cost of solar photovoltaic modules was 3.5 US $/W, while in 2018 it decreased to .5 US $/W. In a word, Figure 1.2 shows the price trend of a solar photovoltaic module.

dollars per peak watt
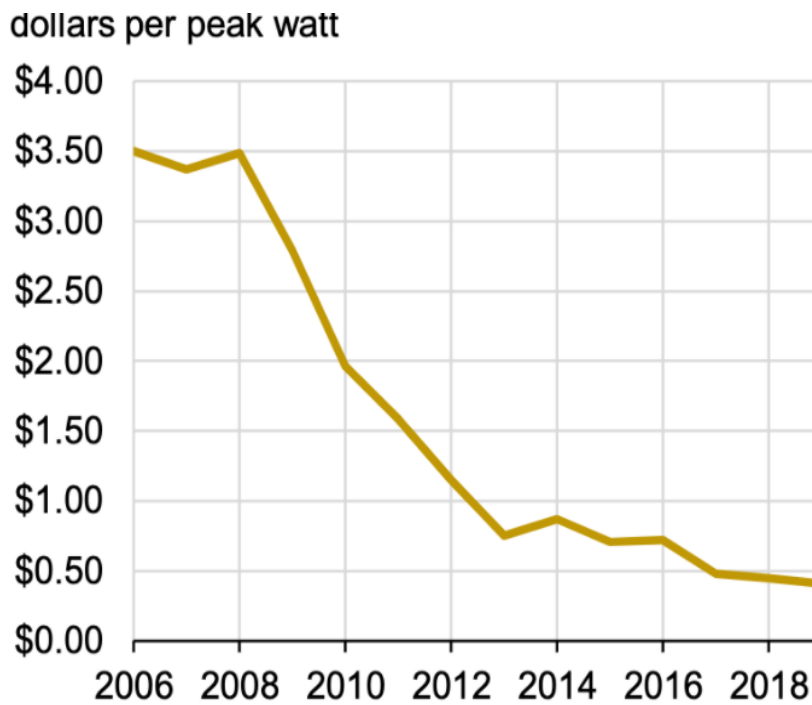
Figure 1.2: The price trend of a solar photovoltaic module

In our thesis, we study several methods in prediction solar energy, linear method (Angstrom Prescott (AP)), nonlinear methods (Simulated Annealing (SA) and Particle Swarm Optimization (PSO)), and Markov Chains. Then compare between methods to have the best results.

Angstrom Prescott (A-P) deals with many parameters (E_r, E_{extra}, S, $S_0, \delta, w, \varnothing$)and using MS Excel program, Simulated Annealing deals with many parameters ($xi, \Delta x, f_{x0}, f_{x0} + \Delta x, \Delta f, T, K(Boltzmann\ constant)$), Particle Swarm Optimization(PSO)deal with many parameters ($xi, fi, f_{best}, p_{best}\ vi, c_1, c_2, G_{best}$), and Markov Chain deal with(MS Excel and Matlab program to apply it).where every method have its equation and figure this is clear in the next chapters.

In both Chapters 1 and 2, an introduction and some basic definitions of linear Angstrom Prescott, nonlinear methods we will in these chapters present several methods of prediction and we will apply two of them on our data of solar radiation and definition of Markov Chains.

In chapter three, making format for data to present the relation between solar radiation and date (for the four seasons of the year)

In chapter four, first, we applied liner (AP) on our data for a year by using an MS Excel program to have linear figure relation between sunshine duration and solar radiation, then we applied two non-linear methods of prediction (SA, PSO) on our data by using Matlab program to have the equation of data than solving it, and finally, we applied Markov Chains on the same data.

Finally, in chapter five we discus all results of each method of prediction through our data, and making a comparison between them to reach to what is the best method of them to have the best prediction of solar radiation.

Chapter Two
Review of Mathematical Prediction Models

This chapter consists of four sections, section 2.1 history of the methods we used , section 2.2 definition of linear (AP) and its properties , In section 2.3 where 2.3.1 is an overview of several non-linear methods (Ante Colony, Delphi Survey Technique, Technology Foresight, Scenario Method, Extrapolation Method), while in 2.3.2 all information about Simulated Annealing is presented in an 2.3.3 overview of Particle Swarm Optimization, and in section 2.4 Markov Chains and why this method is the best .

2.1 AP-SA-PSO-MS History

2.1.1 Angstorm Prescott History

A bibliographical review have expressions proposed by investigators who correlated the relation between solar radiation $\left(\frac{Er}{Eextra}\right)$ with sunshine $(\frac{s}{s0})$, the popular kind of this correlation is Angstrom in 1924 :[15] where

$$\frac{Er}{Eextra} = \alpha + (1-\alpha)\left(\frac{s}{s0}\right),$$ where α is a and 1- α is b, a change introduced by Prescott in 1940:

$$\frac{Er}{Eextra} = a + b\left(\frac{s}{s0}\right).$$ One hundred twenty of researchers tried to evaluate the values of a, b and tabulate them in tables, when we look at the values,

we notice big variability of these two coefficients. Some authors called this relation Angstrom-Prescott technique .

2.1.2 Simulated Annealing History

The majority of the theoretical developments with Simulated Annealing have been for discrete Optimization problems. However Simulated Annealing has also been used as a tool to deal with issues in the continuous location. There is huge interest in the use of Simulated Annealing for worldwide Optimization over areas containing several local and global minima (because of the inherent non-linearity of aim abilities). Fabian (1997) studies the overall performance of Simulated Annealing techniques for locating a global minimum of a feature and Bohachevsky et al. (1986) presents a generalized Simulated Annealing set of guidelines for feature optimization for use in statistical programs.

Optimization of non-prevent abilities entails finding a candidate region through choosing a path from the cutting-edge-day (incumbent) solution and step size to take in this route and evaluating the function at the brand new (candidate) region. If the function fee of this candidate area is a developed over the feature charge of the incumbent place, then the candidate turns into the incumbent. This migration through nearby minima searching for a worldwide minimum continues until the worldwide minimum is discovered or a few termination criteria are reached. Belisle

(1992) provides a unique Simulated Annealing set of guidelines for global optimization, which uses a heuristically motivated cooling timetable.[9] This set of regulations is easy to put into effect and presents a less expensive possibility to existing techniques .

Belisle et al. (1993),[9] talk about convergence residences of Simulated Annealing algorithms finished to continuous talents and apply those outcomes to hit-and-run algorithms applied in international Optimization. His convergence homes are regular with the ones provided through Hajek (1988).[9] and he offers accurate assessment amongst convergence in chance and the stronger almost positive convergence. Zabinsky et al. (1993) [9] extend this portray to an advanced hit-and-run set of rules used for international Optimization. Fleischer and Jacobson (1996) [9] advocate cybernetic Optimization with the resource of way of Simulated Annealing as a method of parallel processing that prolonged the convergence of Simulated Annealing to the global optima. Fleischer (1999) [9] extends the idea of cybernetic Optimization by means of using a manner of Simulated Annealing into the non-prevent area through using probabilistic feedback control to the era of candidate answers. The probabilistic comments control approach of producing candidate answers correctly hastens convergence to a global gold standard the usage of parallel Simulated Annealing on non-stop-variable troubles.

Locatelli (1996) [9] gives convergence properties for a class of Simulated Annealing algorithms for non-stop global Optimization through casting off the limit that the following candidate element has to be generated according to an opportunity distribution whose useful resource is the whole viable set. Siarry et al. (1997) [9] have a look at Simulated Annealing algorithms for globally minimizing capabilities of many continuous variables. Their artwork recognition on how excessive-dimensionality can be addressed by means of the usage of variables discretization, as well as thinking about the design and implementation of several complementary preventing requirements.

Yang (2000) [9] and Locatelli (2000) additionally provide convergence consequences and standards for Simulated Annealing applied to continuous international Optimization issues. Kiatsupaibul and Smith (2000) [9] introduce a widespread -reason Simulated Annealing algorithm to remedy combined-integer linear programs. The Simulated Annealing set of regulations is built using a Markov chain sampling set of guidelines to generate uniformly allocated points on an arbitrary bounded region of an excessive dimensional integer lattice. They display that their set of rules converges in the opportunity to a global maximum appropriate. Romeijn et al. (1999) certainly have a study a Simulated Annealing algorithm that uses

a reflected photo generator for mixed-integer/non-stop global Optimization troubles [9].

In 2017, Wei et al. [2] proposed a Simulated Annealing set of rules for the CVRP with -dimensional loading constraints combining the mechanism of again and again cooling and developing the temperature with today's open space-primarily based packing technique. The computational consequences proved that the form of an aggregate of procedures permits for achieving or improving remarkable-identified solutions for optimum times.

Just currently in 2018, Linan-Garcia et al.[2] Proposed a few different multi-levels metaheuristic set of rules based totally on Simulated Annealing to resolve the CVRP with Stochastic demands. Their algorithm comprises very custom degrees of Annealing along with the Fast Quenching Phase, the Annealing Boltzmann Phase, the Bose-Einstein Annealing Phase, and the Dynamical Equilibrium Phase performed in high-quality degrees of the temperature inside the Simulated Annealing. [2]

2.1.3 Particle Swarm Optimization History:

A particle swarm optimization is a set of rules that deal with the Stochastic optimization technique on a swarm, then its turned in 1995 a proposed in the way of Eberhart and Kennedy, which describe the animal social behaviour (insects, birds, herds, and fishes) all swarms work together for discovering the foods, where they converting the hunt sample consistent

with all studies. The principal layout concept of the PSO set of policies is cautiously related to two sorts of research: One is an evolutionary set of policies, just like an evolutionary set of regulations; PSO additionally makes use of a Swarm mode which makes it simultaneously are seeking for a huge vicinity inside the answer region of the optimized goal characteristic. The distinction is artificial existence, specifically; it researches the synthetic structures with lifestyles developments. In analyzing the behavior of social animals with the synthetic existence idea, for a manner to assemble the Swarm synthetic existence structures with cooperative behavior by the manner of computer, Millonas proposed 5 simple principles: -

(1) Proximity: The entire member in the swarm ought to Implementation of time and space computations easily

(2) Quality: The entire member in the swarm should be able to sense the changes in quality in the environment and make the appropriate response to it

(3) Diverse reaction: The entire member in the swarm shouldn't limit getting the resources in a narrow way

(4) Stability: all the member in the swarm shouldn't change their behaviour mode with every change in environmental

(5) Adaptability: The entire member in the swarm ought to alternate their conduct mode while this variation is worthy. The fourth and fifth are almost have the same meaning

These 5 concepts consist the main characteristics of the artificial existence structures, and that they have emerged as guiding ideas to establish the Swarm artificial existence gadget. In PSO, Particles can update their positions and velocities according to the environment change, particularly; it meets the necessities of proximity and quality [25]. In addition, the Swarm in PSO does no longer limit its motion however constantly searches for the most effective answer in the possible answer space. Particles in PSO can preserve their stable motion inside the search space, whilst trade their motion mode to conform to the exchange within the surroundings. So Particle Swarm systems meet the above 5 principles

In 2002, Miranda and Fonseca [8] proposed an approach, denoted Evolutionary PSO (EPSO), which merged the principles of evolutionary computation with PSO. In their algorithm, the operations of replication (wherein each Particle is changed r times; normally r=1), mutation (on the cognitive, social, and inertia weights), crossover and selection (earlier than assessment) had been used to generate diversity and to permit the fittest Particle to survive and propagate. This is analogous to the mechanism of

survival of the fittest of herbal selection, from the Darwinian idea of evolution [8].

Wang, in 2013, proposed the Diversity Enhanced PSO with Neighborhood Search (DNSPSO) [8], a PSO version that consists of a brand new diversity better mechanism the use of a crossover operation, and a brand new neighborhood search method.

The crossover operation is applied to each dimension of the current Particle's position, by replacing it with the correspondent previous dimension where the Particle was in the search space. This operation is, however, applied according to a uniform random number within the range [0, 1] generated for each dimension. If the generated random number is lower than a predefined probability, the Particle's position is recombined with the previous dimension. Otherwise, it remains unchanged.

This operation creates what those authors called a trial Particle that replaces the current Particle only if its fitness value is lower than the current fitness (for minimization problems).

In flip, the neighborhood seeks strategy apparently combines the G_{best} and l_{best} models, developing more trial Particles, based at the G_{best} and the l_{best} data. This seek method is applied according to a predefined probability, and it turned into evolved to enhance the exploration of the quest space through the debris inside the Swarm

Then, the current Particle is replaced by the most fitted Particle among the current Particle, the trial Particle derived from the G_{best} information and the one from the l_{best} information.

2.1.4 Markov Chains History

Markov approaches within the early twentieth century, publishing his first paper on the topic in 1906. [27] Markov techniques were used for a long time, before Andrey Markov's in the shape of the Poisson method. Markov modified into an interest in analyzing an extension of independent random sequences, so Pavel Nekrasov work hard to prove that independence was necessary for the vulnerable regulation of large numbers to preserve.[27] , Markov confirmed in his paper published in 1906 that below high-quality conditions the common consequences of the Markov chain would possibly converge to a difficult and fast vector of values, so proving a prone regulation of massive numbers without the independence assumption, which have been generally regarded as demand for such mathematical legal guidelines to keep. Markov later used Markov Chains to study the distribution of vowels in Eugene Onegin, written via Alexander Pushkin, and proved a critical restrict theorem for such Chains [27].

In 1912 Henri Poincaré studied Markov Chains on finite groups to study card shuffling. Be considered as an expansion model, introduced by means of Paul and Tatyana Ehrenfest in 1907, and a branching process, so Henry

William Watson and via Francis Galton in 1873,[27] worked after Markov. And after them later found out that their branching procedure has been independently observed and studied around 3 many years in advance by way of Irénée-Jules Bienaymé. So in 1928, Maurice Fréchet became very interested in Markov Chains, and in 1938 a detailed study on Markov Chains was published.

In 1931 [27] Andrei Kolmogorov evolved a theory of continuous-time Markov procedures. Kolmogorov was inspired by Louis Bachelier's 1900 work on fluctuations in the stock market. Also, Norbert Wiener's inspired by Einstein's version of the Brownian motion. He studied a most set of Markov strategies referred to as diffusion procedures, so he derived a set of differential equations describing the approaches.In 1928 Sydney Chapman derived an equation, called" the Chapman–Kolmogorov equation" in a simpler mathematically way than Kolmogorov. The differential equations are now known as the Kolmogorov equations or the Kolmogorov–Chapman equations. Other mathematicians who contributed considerably to the rules of Markov processes encompass William Feller, beginning in the 1930s, after which later Eugene Dynkin, beginning within the Nineteen Fifties.

2.2 Linear Modelling of Global Solar Energy

The researchers have developed linear models to calculate the global solar radiation based on the number of sunshine hours, where the global solar radiation has a linear relation with sunshine hours. The most using models were introduced by (Angström, 1924, Angström, 1929, Angström, 1956, Journel, 1978, Bucciarelli, 1986, Gordon, 1988, Gopinathan, 1986), [1]

At the beginning, we used Angstrom- Prescott to calculate the amount of solar energy. The Ångström–Prescott equation shows the relation between the length of sunshine duration and the solar energy reaches the ground, the equation was reviewed from three special views [19]: - (1) the sensitivity to geographical and seasonal factors, (2) the physical basis, and (3) the accuracy of the empirical models.

The monthly mean daily data for sunshine hours were obtained from the Department of Electrical Engineering Control unit situated in khadoorie University, Tulkarem. The data obtained covered the year (2013) for Tulkarem, Palestine located on latitude 31.9522 N and longitude 35.2332 E.

Various climatic parameters had been utilized in developing empirical relations for predicting the month-to-month common worldwide solar radiation. Among the prevailing correlations, the subsequent relation is the commonly regularly occurring modified shape of the Angstrom-type

regression equation, on the monthly common each day international radiation to the average day by day sunshine hours

A basic problem [21] was in calculating clear sky radiation accurately, this problem appears from the definition, so they modified the Prescott model in 1940 by replacing clear sky radiation with extraterrestrial radiation. This model popularly called the Angstrom-Prescott model is the most commonly used and is given by

$$\frac{E_r}{E_{extra}} = a + b\frac{S}{S_o} \qquad\qquad (1)$$

E_r:-monthly average daily global radiation (KWh/m^2)

E_{extra}: monthly average clear sky daily global radiation for the location (*KWh/m2*)

S: is a bright sunshine hour per day (in hr)

S_O: is Astronomical day length (in hr)

$'a'$ And $'b'$ constant are known as Angstrom constant and they are empirical

$$E_{extra}: \; = 24 * I_{sc} * \left[1 + .033 * cos\left(360 * \frac{d}{365}\right)\right] * \left[cos\theta * cos\delta * sinw + \frac{\Pi w}{180} * sin\theta * sin\delta\right] \qquad\qquad (2)$$

Where

$I_{sc}=1367W/m^2$

d: Day of the year from January 1

ө: Latitude of the location

δ: The solar declination

$$\delta = 23.45 * sin\left[360\left(\frac{284+d}{365}\right)\right] \text{ or } -23.45 * sin\left[360\left(\frac{284+d}{365}\right)\right] \qquad 3$$

The declination angle [33], denoted by δ, varies seasonally due to the tilt of the Earth on its axis of rotation and the rotation of the Earth around the sun. If the Earth were not tilted on its axis of rotation, the declination would always be 0°. However, the Earth is tilted by 23.45° and the declination angle varies plus or minus this amount. Only at the spring and fall equinoxes is the declination angle equal to 0°. The rotation of the Earth around the sun and the change in the declination angle is shown in the animation below.

The declination is zero at the equinoxes (March 22 and September 22), positive during the northern hemisphere summer and negative during the northern hemisphere winter [33]. The declination reaches a maximum of 23.45° on June 22 (summer solstice in the northern hemisphere) and a minimum of -23.45° on December 21-22 (winter solstice in the northern hemisphere). In the equation above, the +10 comes from the fact that the

winter solstice occurs before the start of the year. The equation also assumes that the suns orbit is a perfect circle and the factor of 360/365 converts the day number to a position in the orbit.

ω: The mean sunrise hour angle for the given month

$$\omega = cos^{-1}((-\tan\theta) * \tan\delta) \qquad (4)$$

The mean sunrise hour angle can be computed from the following equation below [3]

$$S_o = \frac{2*\omega}{15} \qquad (5)$$

2-3 Nonlinear Modelling of Global Solar Energy

There are three mathematical typical trends:

1-Linear Trend [24]: by the time will increase or decrease at constant absolute rates of change, consistent with the basic formula:

$$Y = a + b\,X$$

Where Y = the variable analyzed, a = the initial value of the trend (at $x = 0$), b = the absolute change of y per observation period, and X = the time unit (year, month, quarter, etc.), whereby $x = 0$ at the starting point and the time units are continuously updated *(1, 2, 3, n).*

2- Growth Curves, Logistic Curves [24]: this trend like S-shaped, where pass through many steps, moves from the initial phase to the dynamic phase then insert it into a new equilibrium phase once more in the end. It is consistent with the formula:

$$Y = \frac{a}{1+e^{a-b*x}} + b$$

3-Life Cycle Curves: They follow at first a growth curve trend. In a subsequent period, the curve takes a downturn again. Its trend is consistent with the formula:

$$Y = \frac{a}{1+e^{a-b*x}+e^{d-c*x}}$$

The growth concept regularly operates with such depictions of trends [24]. The difference between the logistic trends, moving towards saturation, and so-called 'life cycle curves' is that with the latter – similarly to nature – no new stationery (equilibrium) phase occurs, rather a downturn or waning of the variable in question. These curves are sections of frequency distributions, meaning that both approaches are closely connected or represent a transformation .

There are many methods of nonlinear modelling of global solar radiation, we will give seven methods (Ante Colony, Extrapolation method, The Delphi Survey technique, The Technology Foresight, Particle Swarm Optimization, and Simulated Annealing) and explain each method in few

words, then we will apply the last two method in our application in global solar radiation step by step.

2.3.1 Prediction Methods

2.3.1.1 Ante Colony

Ante Colony is a probabilistic technique for solving computational problems which may be reduced to finding exact paths through graphs. Artificial Ants stand for multi-agent techniques stimulated by means of the conduct of actual ants. The pheromone-based communication of biological ants is often the predominant paradigm used.[16] Combinations of Artificial Ants and local seek algorithms have emerged as a technique of desire for numerous Optimization tasks involving some sort of graph, e.G., car routing and internet routing. The burgeoning hobby in this discipline has led to conferences devoted totally to Artificial Ants, and numerous industrial applications by means of specialized organizations consisting of Ant Optima.

We define Ante Colony as a new general-purpose heuristic algorithm which can be used to solve different combinatorial optimization problems. The new heuristic has the following desirable characteristics:

• It is versatile, in that it can be applied to similar versions of the same problem; for example, there is a straightforward extension from the

traveling salesman problem (TSP) to the asymmetric traveling salesman problem (ATSP).

• It is robust. It can be applied with only minimal changes to other combinatorial optimization

problems such as the quadratic assignment problem (QAP) and the job-shop scheduling problem (JSP).

• It is a population-based approach. This is interesting because it allows the exploitation of positive feedback as a search mechanism [5]

positive feedback as a search mechanism

Explaining ACO through an example (travelling salesman (problem)):

The easiest manner to explain how ant colony Optimization works I through an example. We recollect its software to the travelling salesman problem (TSP). In the TSP a set of locations (e.g. Cities) and the distances between them are given. The hassle includes locating a closed tour of the minimum period that visits to every town one time and most effective as soon as.

To exercise ACO to the TSP, we bear in mind the graph defined by means of associating the set of cities with the set of vertices of the graph. This graph is known as the development graph. Since in the TSP it is feasible to transport from any given town to some different metropolis, the

development graph is completely related and the quantity of vertices is the same to the sort of cities. We set the lengths of the edges among the vertices to be proportional to the distances many of the towns represented by using the one's vertices and we companion pheromone values and heuristic values with the edges of the graph. Pheromone values are changed at runtime and represent the cumulated revel in of the ant colony, whilst heuristic values are hassle structured values that, in the case of the TSP, are set to be the inverse of the lengths of the edge

The ants construct the solutions as follows. Each ant begins from a randomly selected metropolis (vertex of the development graph). Then, at every construction step, its actions along the rims of the graph. Each and continues a reminiscence of its course, and in the next steps, it chooses among the edges that don't cause vertices that it has already been visited. An ant has built an answer as soon as it has visited all of the vertices of the graph. At every creation step, an ant probabilistically chooses the threshold to follow among those who lead to yet unvisited vertices. The probabilistic rule is biased by using pheromone values and heuristic records: the higher the pheromone and the heuristic fee related to aside, the better the probability an ant will pick that precise facet. Once all the ants have completed their tour, the pheromone on the edges is updated. Each of the pheromone values is first of all reduced with the aid of a sure percentage.

Each aspect then gets an amount of extra pheromone proportional to the nice of the solutions to which it belongs (there's one answer in line with ant). This procedure is repeatedly applied until a termination criterion is satisfied.

2.3.1.2 Delphi Survey Technique

The Delphi Survey Technique: popular method using in prediction, hence, it's necessary for specialists people they decide the timing, probability, trends, events, importance and implications of factors about the question or problem [13].

The simple definition of Delphi method is:

-First making the list of questions and statements.

-Second asking the specialists and professional people for introducing their answers and rankings ...etc.

-Third make the report and send it to all.

-Fourth asking the specialists and professional people to review their answers.

-Fifth introduce the second report.

 Application of Delphi Survey :

 1-Use in forecasting.

2-Use in patent participation identity.

3-Use in policy-making.

2.3.1.3 Technology Foresight

First: The terms "technology foresight" and "foresight" could be used interchangeably. The former has been largely superseded amongst policymakers with the aid of the plain label of "foresight", on account of the increasingly wide application of these forms of techniques to non-technological domains. Indeed, there is even wide recognition that technology foresight exercises often take as much account of economic, social and cultural issues as they do technology developments, thereby rendering the label "technology foresight" somewhat misleading [23].

Second: is a prediction methodology for figuring out the maximum probably technological trends in the mid-term future. It is defined as "Systematic attempts to observe the long-term future of science, technology, the economy and society, to identify the emerging technologies that will probably produce the greatest economic and social benefits".

In technology foresight projects, the producers and users of science and technology in the innovation system are brought together to develop a common vision of future developments. The timeframe of foresight usually ranges between 10 and 30 years. From the timeline given by this method,

theorists may craft the rest of society, taking into consideration the tenet that social, political, and economic patterns revolve around technological advancements [23].

2.3.1.4 Scenario Method

- Scenario analysis is a process of analyzing the probability events in future by looking at the results or the alternative scenarios by using the experience of judgment. each scenario tell us a story about "alternative future", and encourages all explore to using their imagination in prediction for developing a perspective on complex events contained in that world.

-Scenario analysis is a process of reading possible destiny occasions by using thinking about alternative possible outcomes or scenarios (using expert judgment, as opposed to quantitative forecasts). Each situation developed tells a tale about an "opportunity" destiny global and encourages folks that discover it to "stretch" their imaginations and drop their preconceived judgments to increase a perspective on complicated occasions contained in that world.

Scenario Planning Example - Circle and Boxes

A neat and sparkling scenario planning example and personalize. It's very clean to change the arrival and content in Edraw to make it the way you like.

Description: A free customizable market analysis template is provided to download and print. Quickly get a head-start when developing your market evaluation diagram. It is completely formatted and prepared with exceptional contents, helping you to keep in advance for your work. With abundant built-in shapes in Edraw, you may create many exclusive styles of advertising and marketing diagrams in keeping with your specific requirements [7]. as shown in figure
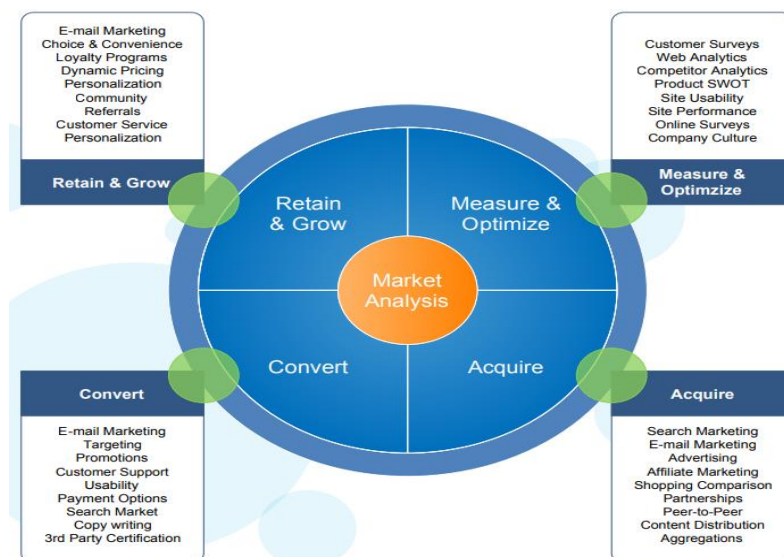
Figure 2.1: Many different kinds of marketing diagrams

2.3.1.5 Extrapolation Method

- Trend analysis (trend Extrapolation) is a famous prediction method depending primarily on identifying, by using the information,[30] historical notes and continuous changing, the objective from Extrapolation is to identify the trend early and we can kept it in future .

Extrapolation method always introduced facts instead of information, then we calculate all statistics about the situation and plotted it beside the time axis to have the curve which we can extrapolate in future,[30] some application of mode Moore's regulation, the annual range of transplants, the gas performance of cars, and the yearly range of transplants.

- the greater Extrapolation by the time, the greater Uncertainty in the event, there is no guarantee that the variable will continue to exchange the way it did in the past, this kind of Extrapolation cares about the forces that change by the time, it's possible to used in complicated events to show exceptional patterns.

Also, we can use Extrapolation in qualitative trends, this kind of trends very difficult to predict in future, because it requires creative and systemic thinking (example: globalization).

What is Extrapolation Statistics?

Extrapolation is a statistical method beamed at know-how the unknown data from the recognized facts. It attempts to predict future statistics primarily based on historical records.[30] For instance, estimating the population size some years in the future based on the cutting-edge population size and its rate of growth .

<u>Extrapolation types: -</u>

1-Linear Extrapolation:[32] For any linear characteristic, linear Extrapolation presents an MS Excellent result whilst the point to be predicted isn't too some distance from the given facts. It is normally executed using drawing the tangent line on the endpoint of the given graph and with a purpose to be extended past the restrict.

2-Polynomial Extrapolation:[32] A polynomial curve can be created with the assist of whole acknowledged statistics or close to the endpoints. This method has generally executed the usage of Lagrange interpolation or Newton's machine of finite series that offers the information. The very last polynomial is used to extrapolate the records the use of the associated endpoints.

3-Conic Extrapolation:[32]A conic section can be created with the assistance of five factors nearer to the stop of the given facts. The conic segment will curve lower back on itself if it's miles a circle or ellipse. But for parabola or hyperbola, the curve will no longer lower back on itself due to the fact it's miles relative to the X-axis.

Extrapolation Formula:

Let us consider the two endpoints in a linear graph (x_1, y_1) and (x_2, y_2) where the value of the point "x" is to be extrapolated, and then the Extrapolation formula is given as (Straight-line equation)

$$y(x) = y_1 + ((x - x_1)/(x - x_2))(y_2 - y_1)$$

Simple Extrapolation Example:

The two given points that lie on the straight line is *(1, 5) and (4, 10).* Determine the value of y at $x = 5$ on the straight line using a linear Extrapolation method.

Solution: Given: $x_1 = 1, \ y_1 = 5$

And $x_2 = 4, \ y_2 = 10$

The linear Extrapolation formula is given as;

$$y(x) = y_1 + ((x - x_1)/(x_2 - x_1))(y_2 - y_1)$$

Substitute the known values in the given formula,

$$y(5) = 5 + \left(\frac{5 - 1}{4 - 1}\right)(10 - 5)$$

$$y(5) = 5 + (4/3)(5)$$

$$y(5) = 5 + 6.65$$

y (5)= 11.65

Therefore *y(5) = 11.65*

2.3.2 Simulated Annealing

Annealing is the natural process of cooling a molten fabric; from a high temperature. If the cooling process is performed under thermal equilibrium conditions, Annealing results in the formation of crystals. The formation of a perfect crystal is equivalent to a state of minimum energy.

Simulated Annealing is a versatile set of rules in handling combinatorial Optimization problems.[18] It can be applied to complex problems, concerning even discontinuous non-differentiable, and non-convex capabilities.

Kirkpatrick et al, who proposed Simulated Annealing for the first time [17], when we make annealing for this method we get the minimal energy of solid-state, when we growing a single crystal from the melt, the low temperature is not a suitable condition to obtain the ground state of matter. the annealing techniques trying to reach a low-temperature state by melting the substance and then decreasing the temperature slowly; this will spend lengthy times at temperatures around the freezing factor. If this is not accomplished, the substance may be outdoor the bounds of equilibrium, and the crystals obtained can have a lot of defects. For the case of glass,

crystals will not form a crystalline order, because the situation is metastable, in which its structure is locally optimal.

A simple Optimization set of rules compares iteratively the outputs of the goal capabilities strolling with a current and neighbouring point inside the domain so that, [17] if the neighboring factor generates a better result than the present-day one, then its miles stored as a base solution for the following generation. Otherwise, the algorithm terminates the procedure without looking at the wider domain for higher effects. So that, the algorithm is prone to be getting trapped in local minima or maxima. Instead, the SA set of rules proposes a powerful approach to this problem via incorporating two iterative loops which are the cooling system for the Annealing manner and the Metropolis criterion. The primary concept at the back of the Metropolis criterion is to be accomplished randomly to greater seeking the neighborhood of the candidate option to keep away from being trapped to neighborhood excessive points. Boltzmann distribution is a quantitative key of the SA method. The following equation gives the probability of any actual state of $x_i = \{x_1, x_2, x_3 ... ... x_n\}$

$$p(x_i) = e^{-\frac{\Delta f(xi)}{KT}} \qquad (6)$$

Where $f(x_i)$ is the configuration of energy, K is Boltzmann's constant, and T is temperature. In case of an Optimization problem,[17] the standard Optimization procedure of SA is given by the following steps:

1. Generate initial solution vector: choose the preliminary random solution x_o for the system we want to optimize, then calculated the aim function

2. Initialize the temperature: we must know the preliminary temperature T to have a successful implementation of SA, if the value was very high we need to decrease it, and if the value was very small.

3. Select a new solution in the neighborhood of the current solution: A new solution $x_0+\Delta x$ is accepted as a new recent solution depending on T. The objective function for $x_0+\Delta x$ and x_0 is represented

$f(x_0+\Delta x)$ and $f(x_0)$, respectively.

4. Evaluation of a new solution: If $f(x_0+\Delta x) \leq f(x_0)$, then $x_0+\Delta x$ is accepted and it replaces x_0, update the existing optimal solution and go to step 6. On the other hand, if $f(x_o+\Delta x) > f(x_o)$, then $x_0+\Delta x$ can also be accepted with a probability base on equation (4).

5. For all duration of the research, we decrease the temperature periodically, the possibility of accepting deteriorating movements will be high.

Repeat step $2 - 6$ until a stopping criterion is met: We finished the computation when we satisfied the termination criterion. Otherwise, step 2 until 6 are repeated. The algorithm of SA is presented by the flowchart

Simulated Annealing algorithm

1 Select the best solution vector x_0 to be optimized
2 Initialize the parameters: temperature T, Boltzmann's constant k
3 while termination criterion is not satisfied do
4   for number of new solution
5   Select a new solution: $x_0 + \Delta x$
6   if $f(x_0 + \Delta x) > f(x_0)$, then
7            $f(new) = f(x_0 + \Delta x); \; x_0 = x_0 + \Delta x$
8   else
9            $\Delta f = f(x_0 + \Delta x) - f(x_0)$
10   random r(0,1)
11   if $r > exp\left(-\frac{\Delta f}{KT}\right)$ then
12               $fnew = f(x_0 + \Delta x), x_0 = x_0 + \Delta x$
13   else
14               $fnew = f(x_0)$
15   end if
16   end if
17             $f = fnew$
18   decrease the temperature T
19   end for
20 end while

Pseudo-code for Simulated Annealing algorithm

The simulation can be performed by many methods:

*by solving the density functions kinetic equations

*by using the Sampling Stochastic method

*by using the Monto Carlo method to generate sample state from the thermodynamic system, [11] it's the same as the Metropolis-Hastings algorithm . The example of this method what we applied in our application (it will be explained in chapter Four)

2.3.3 Particle Swarm

Figure 2.2: The swarm behavior of birds

-Some fishes and birds along with herbal creatures behave as a Swarm. where they coordinate their motions with each other so that their movement does not interfere,[18] actions toward the destination and movements to the centre of the organization (Swarm). in a mid of 1990, they formulated the basic idea of Particle Swarm as an Optimization algorithm.

-The Particle Swarm Optimization (PSO) algorithm [4], is a metaheuristic algorithm based on the concept of Swarm intelligence able to fixing complex mathematical problems present in engineering. It is of tremendous importance noting that handling PSO has a few advantages while as compared with different Optimization algorithms, once it has fewer parameters to adjust.

2.3.3.1 The Basic Model of PSO Algorithm:

Kennedy and Eberhart first set up an approach to the complicated non-linear Optimization trouble by way of imitating the conduct of fowl flocks. They generated the concept of feature Optimization the usage of a Particle Swarm [4]. Consider the global optimum of an n-dimensional function defined by

$$f(x_1, x_2, x_3 \ldots \ldots x_n) = f(\vec{x}) \qquad\qquad (7)$$

Where x_n is the search variable, which represents the set of free variables of the given function. The aim is to find a value $\vec{x}$ such that the function $f(\vec{x})$ is either a maximum or a minimum in the search space.

- The Particle Swarm Optimization (PSO) algorithm is a multi-agent parallel search method that maintains a Swarm of debris and each Particle represents a capability answer within the Swarm. All debris fly through a multidimensional search area where every Particle is adjusting its role in step with its very own experience and that of neighbors. Suppose x_i^t

denotes the position vector of Particle i within the multidimensional seek area at time step t, then the placement of every Particle is updated within the seek space with the aid of

$$x_i^{t+1} = x_i^t + v_i^{t+1} \dots with\ x_i \sim u(x_{min}, x_{max}) \qquad (8)$$

Where vi^t, is the velocity vector of Particle i that drives the Optimization process and reflects both the own experience knowledge and the social experience knowledge from all Particles;

$u(x_{min}, x_{max})$ is the uniform distributions where are x_{min} and x_{max} are its minimum and maximum values respectively.

Therefore, in a PSO method, all particles are initiated randomly and evaluated to compute fitness together with finding the personal best (best value of each particle) and global best (best value of particle in the entire swarm). After that a loop starts to find an optimum solution. In the loop, first the particles' velocity is updated by the personal and global bests, and then each particle's position is updated by the current velocity. The loop is ended with a stopping criterion predetermined in advance [22].

2.3.3.2 Global Best PSO:

The global best PSO (or G_{best} PSO) is a way in which the placement of every Particle is influenced by means of the quality-match particle in the complete Swarm. It uses a star social network topology where the social information obtained from all particles in the entire Swarm [22]. In this method, each particle, $i \in 1, \ldots \ldots n$ where $n > 1$, has a current position in search space x_i, a current velocity v_i, and a personal best position in search space, $p_{best, i}$. The personal best position p_{best} corresponds to the position in search space where i particle had the smallest value as determined by the objective function f, considering a minimization problem. In addition, the position yielding the lowest value amongst all the personal best $p_{best, i}$ is called the global best position which is denoted by G_{best}. The following equations 9 and 10 define how the personal and global best values are updated, respectively.

Considering minimization problems, then the personal best position $p_{best, i}$ at the next time step, $t + 1$ where $t \in [0, \ldots N]$, is calculated as

$$p_{best,i}^{t+1} = \begin{cases} p_{best,i}^{t} & if\ f(x_i^{t+1}) > p_{best,i}^{t} \\ x_i^{t+1} & if\ f(x_i^{t+1}) \leq p_{best,i}^{t} \end{cases} \tag{9}$$

Where $f: R^n \rightarrow R$ is the fitness function. The global best position G_{best} at time step t is calculated as

$$G_{\text{best}} = min\{p_{best,i}^t\}, where\ i \in [1, ..., n]and\ n > 1 \qquad (10)$$

Therefore, it's important to note that the personal best $p_{\text{best, i}}$ is the best position that the individual particle i has visited since the first time step. On the other hand, the global best position is the best position G_{best} is the best position discovered by any of the particles in the entire Swarm

For the G_{best} PSO method, the velocity of the Particle is calculated by

$$v_{ij}^{t+1} = v_{ij}^t + c_1 r_{1j}^t * \left[p_{best,i}^t - x_{ij}^t\right] + c_2 r_{2j}^t * \left[G_{best} - x_{ij}^t\right] \qquad (11)$$

Where

v_{ij}^t is the relative velocity vector of particle i with respect to particle j at time t ;

x_{ij}^t is the relative position vector of particle with respect to particle j at time t ;

$p_{best,i}^t$: is the relative personal best position of particle i with respect to particle j found from initialization through time t;

G_{best} : is the relative global best position of particle i with respect to particle j found from initialization through time t;

$c_1\ and\ c_2$ are positive acceleration constants that are used to level the contribution of the cognitive and social components respectively;

r_{1j}^t and r_{2j}^t are random numbers from uniform distribution $U(0,1)$ at time t.

start

Initialize position $x_{ij}^0, c1, c_2, velocity\ vij^0, evaluate\ fij^0, using\ x_{ij}^0$
D=max. no of dimension, P=max . no of Particles, N=max .no of iterations.

t=0

choose randomly r_{1j}^t, r_{2j}^t

i=1

j=1

$$v_{ij}^{t+1} = v_{ij}^t + c_1 r_{1j}^t * [p_{best,i}^t - x_{ij}^t] + c_2 r_{2j}^t * [G_{best} - x_{ij}^t]$$

$$x_{ij}^{t+1} = x_{ij}^t + v_{ij}^{t+1}$$

$j = j + 1$

$i = i + 1$

Yes

i

Yes

i

$t = t + 1$

Evaluet f_{ij}^t using x_{ij}^t

$f_{ii}^t \leq$ Yes $fG_{best} = f_{ij}^t, p_{best,i}^t = x_{ij}^t$

No

$f_{..}^t <$ Yes $fG_{best} = f_{ij}^t, G_{best} = x_{ij}^t$

No

Yes

t

No

stop

Figure 2.4: The G$_{best}$ PSO algorithm flowchart

45

2.3.3.3 Acceleration Coefficients

The acceleration coefficients c_1 and c_2, together with the random values r_1 and r_2, maintain the Stochastic influence of the cognitive and social components of the Particle's velocity respectively. The constant c_1 expresses how much confidence a Particle has in itself, while c_2 expresses how much confidence a Particle has in its neighbors . There are some properties of c_1 and c_2 [22]:

●When $c_1=c_2= 0$, Then all Particles continue flying at their contemporary speed until they hit the search space's boundary. Therefore, from the equations 11 the velocity update equation is calculated as

$$v_{ij}^{t+1} = v_{ij}^{t} \qquad (12)$$

●When $c_1>0$ *and* $c_2=0$, all Particles are independent. The velocity update equation will be

$$v_{ij}^{t+1} = v_{ij}^{t} + c_1 r_{1j}^{t} * \left[p_{best,i}^{t} - x_{ij}^{t} \right] \qquad (13)$$

On the contrary, when $c_2> 0$ *and* $c_1= 0$ all Particles are attracted to a single point (i.e.G_{best}) in the entire Swarm and the update velocity will become

$$v_{ij}^{t+1} = v_{ij}^{t} + c_2 r_{2j}^{t} * \left[G_{best} - x_{ij}^{t} \right] \qquad (14)$$

● When c_1=c₂, [22] all Particles are attracted towards the average of $p_{best, i}{}^t$ and G_{best}.

● When, $c_1 \gg c_2$ each Particle is more strongly influenced by its personal best position, ensuing in immoderate wandering.[22] In contrast, when $c_2 \gg c_1$ then all Particles are much more influenced by the global best position, which causes all Particles to run prematurely to the optima.

Normally c_1 and c_2, are static,[22] with their optimized values being found empirically. Wrong initialization of c_1 and c_2 may result in divergent or cyclic behavior. From the special empirical researches, it has been proposed that the two acceleration constants should be c_1=c_2= 2

a hat must be set are widely discussed in the literature.

The example of this method (PSO) what we applied in our application (will be explained in chapter 4).

2.4 Markov Chains

-A collection of random variables $X_0, X_1, \ldots$ With values in a countable set S is a Markov chain if at any time n, the future states (or values)

$X_n +1, X_n +2, ..$ rely on the records $X_0, .., X_n$ most effective through the prevailing state X_n. Markov Chains are essential Stochastic approaches which have many various programs. This is because a Markov chain

represents any dynamical gadget whose states satisfy the recursion $X_n = f(X_n - 1, Y_n), n \geq 1$, in which Y_1, Y_2 ... Are impartial and identically disbursed and f is a deterministic function [19]. That is, the new state X_n is truly a feature of the closing kingdom and an auxiliary random variable. Such system dynamics are normal of those for queue lengths in name facilities, stresses on substances, ready times in production and provider centers, inventories in deliver Chains, parallel-processing software, water stages in dams, coverage budget, inventory charges, etc.

-Markov Chain is stochastic model showed us a sequence of possible activities where the probability of each activity depends only on the state attained in the previous activities [27]. if accountably infinite sequence move in discrete time it called (Discrete-Time Markov Chain), if accountable infinite sequence move in continuous time it called (Continuous-Time Markov Chain).

- Some applications of the Markov Chain in queues of customers in the airport, the dynamics number of animals, [29] currency exchange rates and studying how cruiser system in motor vehicles work. briefly, we can find it in Bayesian statistics application, physics, chemistry, thermodynamics, economics, processing for signal and speech, finance, and prediction solar radiation (that what we do in our thesis) which are used for simulating sampling from complex probability distributions

-In a Markov chain, we have a sequence of random variables, which we can think of as describing the state of a system, X_1, X_2, X_n what makes them Markov is a conditional independence property that says that each state only depends on the previous state. That is:

$$P(X_n | X_1, X_2, X_n - 1) = P(X_n | X_n - 1)$$

The diffusion of a single particle offers us a simple example of this. - Let X_n be the position of a particle at the time n. Suppose at each time step, the Particle jumps either one unit to the left or right or stays in the same place. We can see that X_n depends on $X_n - 1$, but that if we know $X_n - 1$ the previous values of X are irrelevant. We also can see that this is a Stochastic Model of the deterministic diffusion we've got studied. If there are numerous particles, we will use the regulation of big numbers to anticipate that a set fraction of them bounce to the left and proper. Remember that we saw that the placement Xn can have a Gaussian distribution for massive n, because of the central limit theorem

A Stochastic process $X = \{X_n : n \geq 0\}$ on a countable set S is a Markov Chain if, for any $i, j \in S$ and $n \geq 0$,

$$P\{X_n + 1 = j | X_0, .., X_n\} = P\{X_n + 1 = j | X_n\}, \qquad (15)$$

$$P\{X_n + 1 = j | X_n = i\} = p_{ij} \qquad (16)$$

The p_{ij} is the probability that the Markov chain jumps from state i to state j. These transition probabilities satisfy $\sum_{j\in\delta} p_{ij} = 1$, $i \in S$, and the matrix $P = (p_{ij})$ is the transition matrix of the chain[19].

Condition (15), called the Markov property, says that, at any time n, the next state $X_n + 1$ is conditionally independent of the past $X_0, \ldots, X_n - 1$ given the present state X_n. In different words, the following state is depending on the past and present simplest via the prevailing state. The Markov assets is a primary condition this is satisfied by way of the country of many Stochastic phenomena. Consequently, Markov Chains, and associated continuous-time Markov methods, are natural models building or blocks for applications.

Condition (16) Simply says the transition probabilities do now not depend upon the time parameter n;[19] the Markov chains, consequently "time-homogeneous". If the transition probabilities have been features of time, the manner Xn might be a non-time-homogeneous Markov chain. Such Chains are like time-homogeneous Chains, but the time dependency introduces added accounting details that we will not address here. Since the state space S is countable, we will sometimes label the states by integers, such as $S = \{0, 1, 2, \ldots\}$ $(or\ S = \{1, \ldots, m\})$. Under this labeling, the transition matrix has the form

$$P = \begin{bmatrix} p_{00} & p_{01} & p_{02} & \cdots & \cdots & \cdots \\ p_{10} & p_{11} & p_{12} & \cdots & \cdots & \cdots \\ p_{20} & p_{21} & p_{22} & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \end{bmatrix}$$

Example of Markov Chains: Binomial Markov Chain. A Bernoulli method is a chain of independent trials in which every trial outcomes in success or failure with respective probabilities p and $q = 1 - p$. Let Xn denote the number of successes in n trials, for $n \geq 1$. By direct reasoning, it follows that X_n has a binomial distribution with parameters n and p:

$P\{X_n = k\} = \binom{n}{k} p^k * (1 - p)^{n-k}$, $0 \leq k \leq n$. Now, suppose at the nth trial that $X_n = i$. Then at the next trial, $X_n + 1$ will equal $i + 1$ or i with probabilities p and $1 - p$, respectively, regardless of the values of $X_1, \ldots, X_n - 1$. Thus Xn is a Markov chain with transition probabilities $p_{i,i+1} = P$, $p_{ii} = 1 - P$ and $p_{ij} = 0$ otherwise. This binomial Markov chain is a special case of the following random walk.

Why Markov Models?

1. Markov models are a great way to version neighborhood, overlapping units of statistics, which reflect cues to our know-how of regions.

2. Markov Chains offer a Stochastic model of diffusion that applies to individual particles, which gives us the inspiration for diffusion we've got studied.

3. This Stochastic diffusion also gives a useful version of the unfolds of data at some stage in the image.

Chapter Three

Numerical Results

3.1 Sampling Data Processing

Sampling Data Processing: it is a process that first, we calculate data and translate to usable information it to information be able to use. Usually, we applied it to professional scientist's data. It's very important to process data correctly in order to not affect negatively output data [31].

3.1.1 Purpose, Scope and Responsibilities

1- The personal data must be processed by the data processor as the conditions in Data Processing agreement.

2- The Data Processor shall process personal data for the limited purpose of performing the obligations set out under the agreement. Data may, for that purpose, be processed by any of the Data Processor's entities.

3- Data processing by the Data Processor shall include such actions as may be specified in the agreement.

4- The term of this Data Processing agreement shall continue until the latter of the following: the termination of the Agreement, or the date at which the Data Processor ceases to process personal data for the Data Controller [6].

Some types of data are not processed by the Data Processor:

* Financial data

* Personal data about people who committed criminal offences

* Personal data about the economy, debt, sick days, taxes, family relations, residential circumstances, car, [6] personality tests, exams or CV

-We study every value we have in our data and format it, to study the relationship between the date and the solar radiation for all year and for seasons (Spring, Autumn, Summer and Winter) to study the behavior
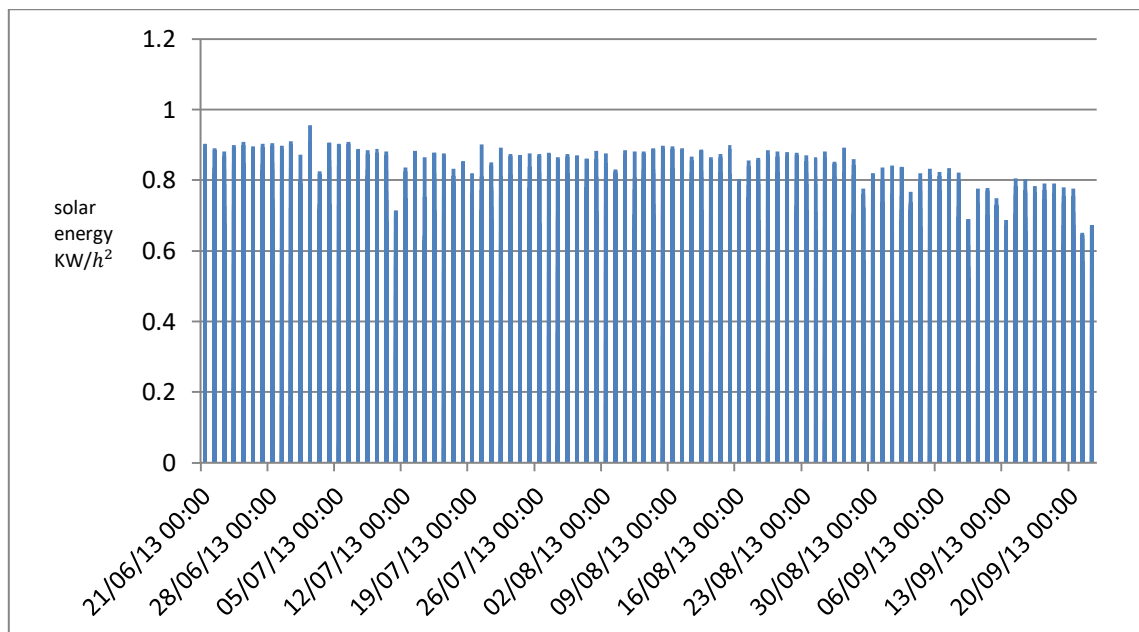
Figure 3.1: for the Summer season

This figure shows us the relation between date and solar radiation for Summer (from 21/06/2013 to 22/09/2013) from the figure [we note that the

maximum is .956, the minimum is 0 and the average is 0.27388] .In summer the measurements of solar radiation begin at (6:00 or 7:00) and ends at (20:00) i.e during the existence of sun in daytime and reach the peak at (12:00 or 13:00) in Tulkarm-Palestine
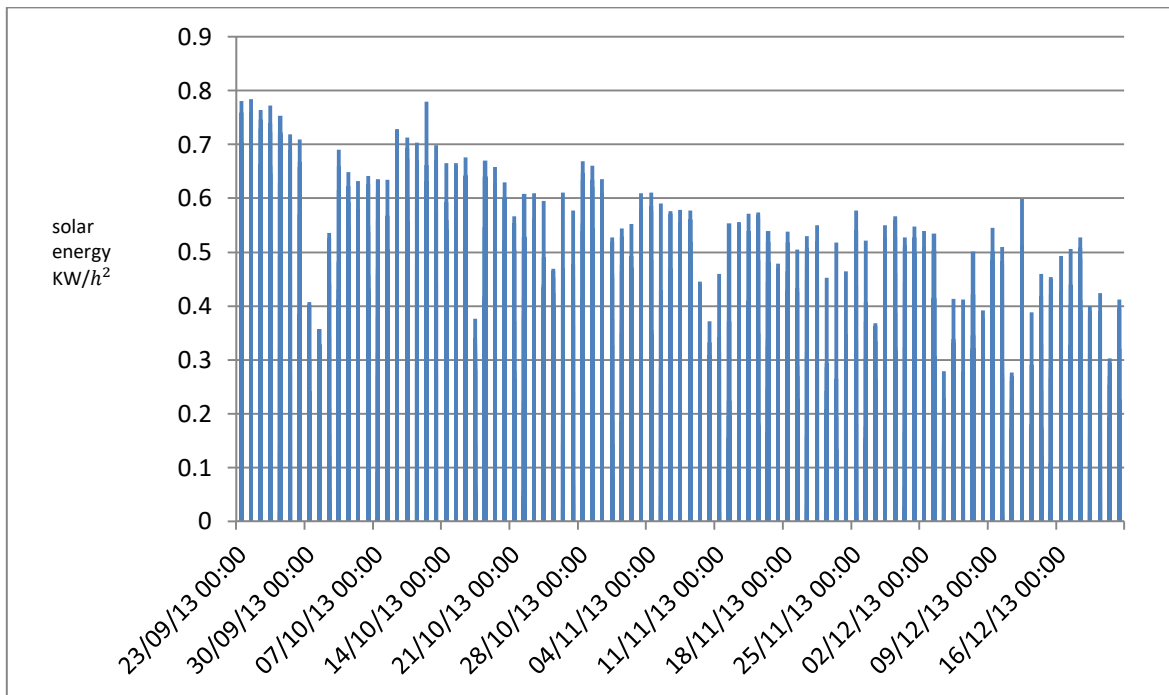
Figure 3.2: for the Autumn season

Figure 3.2 shows us the relation between date and solar radiation for Autumn (from 23/09/2013 to 20/12/2013) from figure [we note that the maximum is .784, the minimum is 0 and the average is 0.140597] .In summer the measurements of solar radiation begin at (7:00 or 8:00) and ends at (18:00 or 19:00) i.e during the existence of sun in daytime and

reach the peak at (12:00 or 13:00 or 14:00) in Tulkarm-Palestine
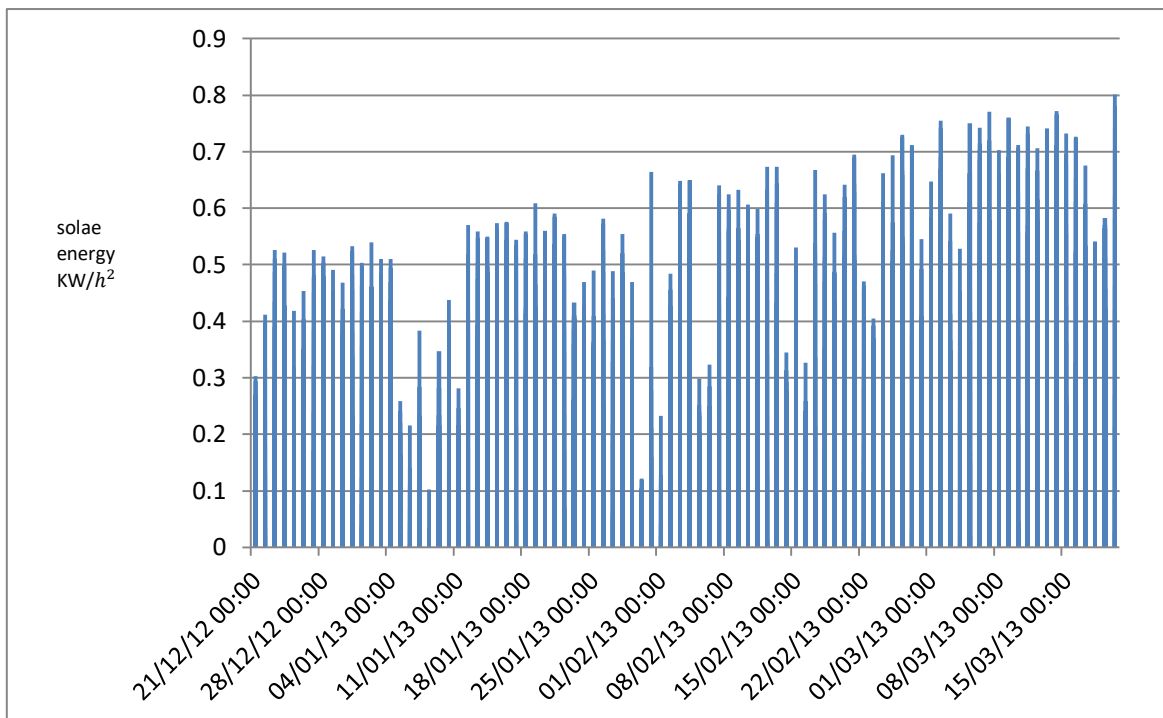
Figure 3.3: The Winter season

This figure shows us the relation between date and solar radiation for Winter (from 21/12/2013 to 20/03/2013) from figure [we note that the maximum is .801, the minimum is 0 and the average is 0.140877] In summer the measurements of solar radiation begin at (6 8:00) and ends at (19:00) i.e during the existence of sun in daytime and reach the peak at (12:00 or 13:00 or 14:00) so number of sunshine hours during Winter is

less than other seasons in Tulkarm-Palestine, a Fact that is reasonable

The chart shows solar energy KW/h^2 on the y-axis (ranging from 0 to 1.2) versus dates on the x-axis from 21/03/13 00:00 to 20/06/13 00:00.
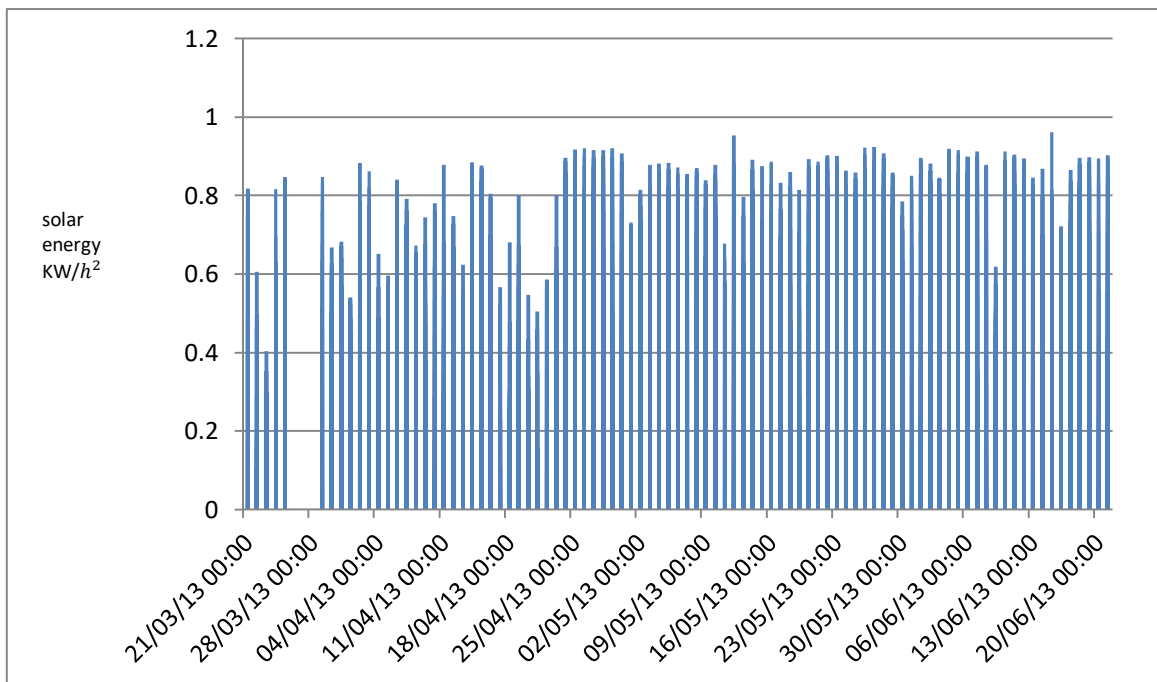
Figure 3.4: for Spring season

This figure shows us the relation between date and solar radiation for Spring (from 21/03/2013 to 21/06/2013) from figure [we note that the maximum is .962, the minimum is 0 and the average is 0.257007] .In summer the measurements of solar radiation begin at (6:00 or 7:00) and ends at (20:00) i.e during the existence of sun in daytime and reach the peak at (13:00 or 14:00) in Tulkarm-Palestine.

 We have some notes from these figures:

1-In Summer we have the most hours for solar radiation.

2-The peak value for solar radiation almost the same for all seasons.

3-The average solar radiation has the greatest value in Summer season

4-The maximum solar radiation in the Spring season.

The minimum solar radiation of course is the same for all seasons equal to zero

3-2 Numerical Solutions for Prediction Methods

In this section, we will show step by step how we applied each of (linear, nonlinear, Markov Chains) prediction methods of solar radiation on our data for a year and what is the results of each method.

3.2.1 Linear Modelling of Global Solar Energy

When anyone reads the title he thinks it's easy to apply a linear model but we faced some problem .So in this chapter, we will explain all steps to apply the Angstrom liner model.

We use the data in our study that we take it from equipment and machines used to measure solar radiation in our university (Palestine Technical University khadoorie in Tulkarm). Estimating Angstrom-Prescott coefficient and developing a correlation between sunshine hours and global solar radiation [13].

First I calculate Er where

$$Y1 = (x_1 + x_2 + x_3 + x_4 + x_5 \ldots \ldots x_{24})/24 \qquad (17)$$

x is solar radiation every hour along the day and Y is the average global solar radiation in day, then $E_r0 = (Y_1 + Y_2 + Y_3 + \ldots \ldots Y_{30})/30$ *(18)*

Where E_{r0} is average global solar radiation in month?

From equation two where $E_r = 24 * E_{r0}$ *(19)*

A second step we want to found Eextra from equation (2) in section 2.1

$$E_{extra} = 24 * Isc * \left[1 + .033 * cos\left(360 * \frac{d}{365}\right)\right] * \left[cos\theta * cos\delta * sinw + \frac{\Pi w}{180} * sin\theta * sin\delta\right]$$

Then we found each of δ and w from equations (3, 4) in section (2.1) and as we know from chapter two $I_{sc} = \frac{1367 W}{m^2}$,

$$\delta = 23.45 * sin\left[360\left(\frac{284+d}{365}\right)\right],$$

$\omega = cos^{-1}((-\tan\theta) * \tan\delta))$ now we can find Eextar

Finally, we found the mean sunrise hour angle $s_o = \frac{2*\omega}{15}$.

After we applied all equation in MS Excel program for every month in year we have 12 values for Eextra and 12 values for E_r

to calculate S we read every value for every hour in a year and take the value more than *120watt/m²* after many steps I find this value for all year

and we have 12 value, for clarification , I take May month as an example

every value more than .12 we take it so

[(11+12+12+12+12+12+12+11+12+11+12+12+11+12+9+12+12+12+11+

12+12+12+12+11+12+12+12+12+11+11+12)

Note: Sunshine duration is the duration of time that the floor surface is irradiated with the aid of direct sun radiation (i.e. Sunlight achieving the earth's floor immediately from the sun). In 2003, WMO described sunshine duration because of the duration during which direct sun irradiance exceeds a threshold value of 120watt/m^2. This price is equivalent to the level of sun irradiance rapidly after dawn or quickly earlier than sundown in cloud-free situations. It becomes decided by way of evaluating the sunshine duration recorded the use of a Campbell-Stokes sunshine recorder with the real direct solar irradiance [14].

Table (3.1): All value for every parameter $(d, S, W_0, W, H_0, H_1, H_2, E_{r0})$ for each month in the year.

$E_r o$	$H2$	H_1	H_0	W	W_0	S	D	Months
0.113952499	-0.236374486	0.757568627	1.028412	76.90749	0.226524	-17.7823	31	Jan
0.147111607	-0.127155546	0.802780211	1.017394	83.81727	0.1077	-8.67004	59	Feb
0.192617819	0.058790552	0.814368765	1.00071	92.56	-0.04467	3.618542	90	Mar
0.220863475	0.254955447	0.777014488	0.984327	100.5914	-0.1838	14.587	120	Apr
0.297238844	0.399715295	0.726689918	0.971734	106.4934	-0.28391	21.89848	151	May
0.29438722	0.42634505	0.715671405	0.967011	107.6072	-0.30249	23.18449	181	Jun
0.285259408	0.324528378	0.754934784	0.971164	103.4043	-0.23182	18.17103	212	Jul
0.277817204	0.135882265	0.804552169	0.983336	95.77245	-0.10058	8.104609	243	Aug
0.22971577	-0.058497957	0.814092334	0.999574	87.29851	0.047132	-3.81782	273	Sep
0.168723118	-0.206649056	0.774403886	1.016418	79.04765	0.189992	-15.0562	304	Oct
0.123673611	-0.276526411	0.726095604	1.028412	73.44546	0.284928	-21.9699	334	Nov
0.103532257	-0.286011756	0.716539478	1.033	72.47913	0.301053	-23.0859	365	Dec

$$E_{Extar} = 24 * I_{sc} * \left[1 + 0.33 * cos\left(360 * \left(\frac{d}{356}\right)\right)\right] * [cos\theta * cos\,\delta * sinw +$$

$$\left(\frac{\Pi w}{180}\right) * sin\theta * sin\delta]$$

We take $H_0 = \left[1 + 0.33 * cos\left(360 * \left(\frac{d}{356}\right)\right)\right]$,and $H_1 = cos\theta * cos\,\delta * sinw$

and $H_2 = \left(\frac{\Pi w}{180}\right) * sin\theta * sin\delta$.

we divided the equation in three parts to have a clearer vision for what we are doing (the explaining for all steps just found in our thesis)

Table (3.2): All values for every parameter($E_r, E_{extar}, S, S_0, \frac{Er}{Eextra}, S/S_0$).

S/So	S	So	E_r / E_{extra}	E_{extra}	E_r
0.673200956	6.903225806	10.2543	0.403731615	6.773955461	2.734859976
0.766974574	8.571428571	11.1756	0.385503332	9.158620113	3.530678568
0.775558736	9.571428571	12.3413	0.413466134	11.18066821	4.622827656
0.760502419	10.2	13.4122	0.437994909	12.10224888	5.3007234
0.820159927	11.64555161	14.1991	0.609364155	11.70684589	7.133732256
0.836375004	12	14.3476	0.672251708	10.50989264	7.06529328
0.870370011	12	13.7872	0.757390499	9.039228513	6.846225792
0.906887463	11.58064516	12.7697	0.869856914	7.665183537	6.667612896
0.88489485	10.3	11.6398	0.869023022	6.344110965	5.51317848
0.850854647	8.967741935	10.5397	0.765845084	5.287433341	4.049354832
0.844163819	8.266666667	9.79273	0.627676302	4.728817474	2.968166664
0.747712474	7.225806452	9.66388	0.321289382	7.733757511	2.484774168
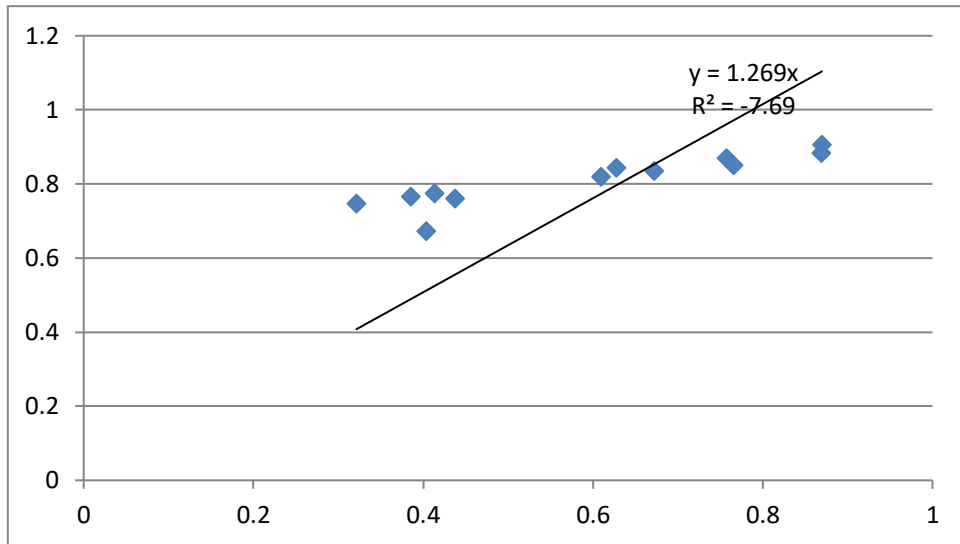
Figure 3.5: The relation between $\dfrac{E_r}{E\text{extra}}$ and $\dfrac{S}{So}$

3.2.2 Nonlinear Modelling of Global Solar Energy

3.2.2.1 Simulated Annealing (SA)

From Pseudo-code for Simulated Annealing algorithm in section 2.3.2, we applied in our application step by step. , First I want to export equation from data by Matlab program

The code in Matlab:

```
close all
x=date1;
y=solar;
plot(x,y);
title('Swarm')
xlabel('day')
ylabel('solar')
polyfit(x,y,2)
```

 Figure (3.6) The coefficient, so the equation (between solar and data) will be 0.0046x+.1091
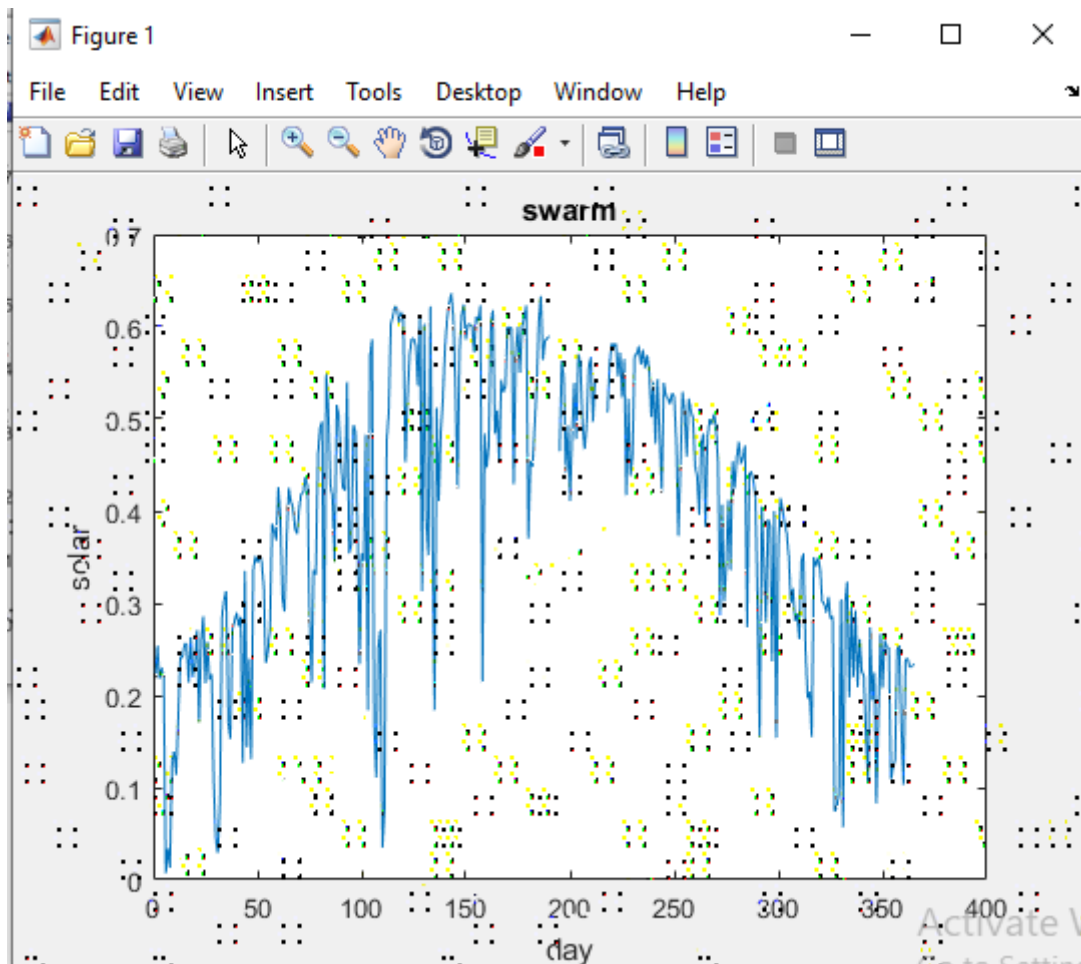
Figure 3. 7:The relation between solar radiation and the days of the year.

The numerical solution for (SA)in solar radiation application

$$f(x) = .0046x + .1091$$

$T = T_{Max} = 54.6°C$ $\qquad\qquad\qquad k = 1.380658 * 10^{-23}(j/k)$

$x_0(i) = 0, 0.1, 0.2, 0.3, 0.4, -0.1, -0.2, -0.3, -0.4$

Solution: -

Step (1):-

In this step I find $\Delta x, f(x_0)$ and $f(x_0 + \Delta x)$ we note that

$f(x_0 + \Delta x) > f(x_0)$ so $f(new) = f(x_0 + \Delta x)$

$x_0 = 0$ $\qquad\qquad\qquad\qquad \Delta x = x_1 - x_0 = 0.1 - 0 = 0.1$

$f(x_0) = .1091$ $\qquad\qquad\qquad f(x_0 + \Delta x) = f(0.1) = 0.10956$

$f(x_0 + \Delta x) > f(x_0)$ ..so $f(new) = f(x_0 + \Delta x) = .10956$

$(x_0 = 0.1)$

Step (2):-

In this step I find x_0 and Δx ($x_1 = 0.1$ and $x_2 = 0.2$), $f(x_1)$ and $f(x_1 + \Delta x)$ we note that $f(x_1 + \Delta x) > f(x_1)$ so $f(new) = f(x_1 + \Delta x)$

$x_1 = 0.1$ $\qquad\qquad\qquad\qquad \Delta x = x_2 - x_1 = 0.2 - 0.1 = 0.1$

$f(x_1) = f(0.1) = 0.10956$ $\qquad f(x_1 + \Delta x) = f(0.2) = 0.11002$

$f(x_1 + \Delta x) > f(x_1)..so\ f(new) = f(x_1 + \Delta x) = 0.11002$

$x_1 = x_1 + \Delta x = 0.2$

Step (3):-

In this step I find x_2 and Δx ($x_2 = 0.2\ and\ x_3 = 0.3$), $f(x_2)$and $f(x_2 + \Delta x)$we note that f$(x_2 + \Delta x) > f(x_2)$ so $f(new) = f(x_2 + \Delta x)$

$x_2 = 0.2$ $\qquad\qquad\qquad\qquad \Delta x = x_3 - x_2 = 0.3 - 0.2 = 0.1$

$f(x_2) = f(0.2) = 0.11002$ $\qquad f(x_2 + \Delta x) = f(0.3) = 0.11048$

$f(x_2 + \Delta x) > f(x_2)..so\ f(new) = f(x_2 + \Delta x) = 0.11048$

$$x_2 = x_2 + \Delta x = 0.3$$

Step (4):-

In this step I find x_3 and Δx ($x_3 = 0.3\ and\ x_4 = 0.4$), $f(x_3)$and $f(x_3 + \Delta x)$we note that $f(x_3 + \Delta x) > f(x_3)$ so $f(new) = f(x_3 + \Delta x)$

$x_3 = 0.3$ $\qquad\qquad\qquad\qquad \Delta x = x_4 - x_3 = 0.4 - 0.3 = 0.1$

$f(x_3) = f(0.3) = 0.11048$ $\qquad f(x_3 + \Delta x) = f(0.4) = 0.11094$

$f(x_3 + \Delta x) > f(x_3)..so\ f(new) = f(x_3 + \Delta x) = 0.11094$

$$x_3 = x_3 + \Delta x = 0.4$$

Step (5):-

In this step I find x_4 and Δx ($x_4 = 0.4$ and $x_5 = -0.1$), $f(x_4)$and $f(x_4 + \Delta x)$we note that $f(x_4 + \Delta x) < f(x_4)$ so we nead to find Δf , T and

$$e^\wedge(^{-\frac{\Delta f}{KT}})$$ then take disution

$x_4 = 0.4$ $\qquad\qquad\qquad$ $\Delta x = x_5-x_4= -0.1 - 0.4 = -0.5$

$f(x_4) = f(0.4) = 0.11094$ $\qquad$ $f(x_4 + \Delta x) = f(0.4 + -.5) = 0.1045$

$f(x_4 + \Delta x) < f(x_4)$.. so we want to find Δf

$\Delta f = f(x_4 + \Delta x) - f(x_4) = 0.1045 - .11094 = -0.00644$

T in kelven..$= 54.6 + 273 = 327.6$ kelven

$$k = 1.380568 * 10^{-23} * 1000 = 1.380568 * \frac{10^{-20}kj}{kw}$$

$KT = 4.51475166 * 10^{-18}Kw$

$e^\wedge(^{-\Delta f}/KT)$ very high and $\gg r$

$$\text{so } f(new) = f(x_4) = f(0.4) = 0.11094$$

$$x_4 = x_4 + \Delta x = -.1$$

Step (6): -

In this step I find x_5 and Δx ($x_5 = -.1$and $x_6 = -.2$), $f(x_5)$and $f(x_5 + \Delta x)$we note that $f(x_5 + \Delta x) > f(x_5)$ so $f(new) = f(x_5 + \Delta x)$

$x_5 = -0.1$ $\qquad\qquad\qquad\qquad$ $\Delta x = x_6 - x_5 = -0.2 - -0.1 = 0.1$

$f(x_5) = f(-0.1) = 0.1045$ $\qquad$ $f(x_5 + \Delta x) = f(-0.2) = 0.1081$

$f(x_5 + \Delta x) > f(x_5)..$ so $f(new) = f(x_5 + \Delta x) = f(x_5) = 0.11081$

$$x_5 = x_5 + \Delta = -0.2$$

Step (7): -

In this step I find x_6 and Δx ($x_6 = -.2$ and $x_7 = -0.3$), $f(x_6)$ and $f(x_6 + \Delta x)$ we note that $f(x_6 + \Delta x) < f(x_6)$ so we nead to find Δf , T and

$e^{\wedge}(-\frac{\Delta f}{KT})$ then take disution

$x_6 = -0.2$ $\qquad\qquad\qquad\qquad$ $\Delta x = x_7 - x_6 = -0.3 - -0.2 = -0.1$

$f(x_6) = f(-.2) = 0.1081$ $\qquad$ $f(x_6 + \Delta x) = f(-0.3) = 0.10772$

$f(x_6 + \Delta x) < f(x_6)..$ so we want to find Δf

$\Delta f = f(x_6 + \Delta x) - f(x_6) = 0.10772 - .1081 = -3.8 * 10^{-14}$

We want to decrease $T = (T\ average) = 14.65922$....note [we calculate T average from data we have]

$T\ in\ kelven = 14.65922 + 273 = 287.65922\ kelven$

$k = 1.380568 * 10^{-23} * 1000 = 1.380568 * \dfrac{10^{-20}kj}{kw}$

$KT = 3.97133114 * 10^{-18}Kw$

$e^{\wedge}(-\Delta f/KT)$ very high and $\gg r$

$$\text{so } f(new) = f(x_6) = f(-.2) = 0.1081$$

$$x_6 = x_6 + \Delta x = -.3$$

Step (8): -

In this step I find x_7 and Δx ($x_7 = -.3 \text{ and } x_8 = -0.4$), $f(x_7)$ and $f(x_7 + \Delta x)$ we note that $f(x_7 + \Delta x) < f(x_7)$ so we nead to find Δf, T and

$e^{\wedge}(-\frac{\Delta f}{KT})$ then take disution

$x_7 = -.3$ $\hspace{3cm}$ $\Delta x = x_8 - x_7 = -.4 - -.3 = -0.1$

$f(x_7) = f(-.3) = 0.10772$ $\hspace{1cm}$ $f(x_7 + \Delta x) = f(-.4) = 0.10726$

$f(x_7 + \Delta x) < f(x_7)$.. so we want to find Δf

$\Delta f = f(x_7 + \Delta x) - f(x_7) = 0.10726 - .10772 = -4.6 * 10^{-14}$

We want to decrease $T = $ (T min) =-125.1....note [we calculate T min from data we have]

$T \text{ in kelven}.. = -125.1 + 273 = 147.9 \text{ kelven}$

$$k = 1.380568 * 10^{-23} * 1000 = 1.380568 * \frac{10^{-20}kj}{kw}$$

$KT = 147.9 * 1.380658 * 10^{-20} Kw$

$e^{\wedge}(-\Delta f/KT)$ very high and $\gg r$

so $f(new) = f(x_7) = f(-.3) = 0.10772$

$x_7 = x_7 + \Delta x = -.4$

Step (9): -

$f(x_8) = f(-.4) = .10726$ □

Simulated Annealing have many advantages such that it can deal with arbitrary systems and cost functions, statistically guarantees to find an optimal solution and is relatively easy to code, even for complex problems, generally gives a ``good" solution

This method is long but its steps are very clear and as shown above and we can apply it in many applications, and in (predicting solar radiation) we reached many results:

1-) the probability that the solar radiation at a specific day (at 10am) will remain unchanged from the previous day is 0.10956

2-) the probability that the solar radiation on a specific day (at 10 am) will increase by 0.1 from the previous day is 0.11002

3-) the probability that the solar radiation on a specific day (at 10 am) will increase by 0.2 from the previous day is .11048

4-) the probability that the solar radiation on a specific day (at 10 am) will increase by 0.3 from the previous day is 0.11094

5-) the probability that the solar radiation on a specific day (at 10 am) will increase by 0.4 from the previous day is 0.11094

6-) the probability that the solar radiation on a specific day (at 10 am) will decrease by 0.1 from the previous day is 0.1081

7-) the probability that the solar radiation on a specific day (at 10 am) will decrease by 0.2 from the previous day is 0.1081

8-) The probability that the solar radiation on a specific day (at 10 am) will decrease by 0.3 from the previous day is 0.10772

9-) the probability that the solar radiation on a specific day (at 10 am) will decrease by 0.4 from the previous day is 0.10726

3.2.2.2 Particle Swarm Optimization (PSO)

We know the equation as we explain above in (2.2.3) now we can apply all steps as it showed in flow chart (1) in the same section.

The numerical solution for (PSO) in solar radiation application:

Find the maximum of the function

$$f(xi) = .0046x + .1091 \quad with - .4 \leq x \leq .4$$

With using the PSO algorithm. Use 9 particles with the initial positions

$x_1 = -.4, x_2 = -.3, x_3 = -.2, x_4 = -.4, x_5 = 0, x_6 = .1, x_7 = .2, x_8 = .3,$ and $x_9 = .4$. Show the detailed computations?

In this steps we take the value of $x_i{}^0$ as the same of initial values of x_i ,then

we want to find $f_i{}^0$ by substituting all values of x_i in the

equation ($f(x_i) = .0046x + .1091$)

Then find f best due to all values of $f_{best,i}{}^t > f_i{}^0$ so $p_{best,i}^t = x_i{}^t$ then find

G best where $=min\{p_{best,i}^t\}$ and we know the values of $r_1{}^t, r_2{}^t$ and c_1 and c_2

now we can found v_i^t then $x_i^{t+1} = x_i^t + v_i^{t+1}$ and so until we get the final

solutions of fi we show that step by step.

Step (1):-

$x_1^0 = 0, x_2^0 = .1, x_3^0 = .2, x_4^0 = .3, x_5^0 = .4, x_6^0 = -.1, x_7^0 = -.2$

$x_8^0 = -.3 \qquad x_9^0 = -.4$

$f_1^0 = .1091, f_2^0 = .10956, f_3^0 = .11002, f_4^0 = .11048,$

$f_5^0 = .11094, f_6^0 = .10865, f_7^0 = .10818, f_8^0 = .10772,$

$f_9^0 = .10726$

$f_{Best} = max(f_i^0) = .11094$

if $f_{best,i}^t > f_i^0$ then $p_{best,i}^t = x_i^t$

When $t=0$

$$p^0_{best,1} = 0 \; , p^0_{best,2} = .1 \; , p^0_{best,3} = .2 \; , p^0_{best,4} = .3$$

$$p^0_{best,5} = .4 \; , p^0_{best,6} = -.1 \; , p^0_{best,7} = -.2 \; , p^0_{best,8} = -.3$$

$$p^0_{best,9} = -.4$$

Set the initial velocity of each Particle to zero:-

$$v^0_i = 0 \ldots v^0_1 = 0, v^0_2 = 0, v^0_3 = 0 \ldots \ldots v^0_9 = 0$$

From 2-2-2 the acceleration $c_1{=}c_2{=}2$

Step (2):

$$G_{best} = min\{p^t_{best,i}\} \qquad i = 1,2,3, \ldots \ldots \ldots 9$$

The maximum personal best is $p^1_{best,5} = .4$

Thus $G_{best} = .4$

Step (3):-

Considering the random number

Note: we calculate the random number from Matlab and we discover that it is any number between [0, 1] in Matlab

$$Rand\ (2,\ 2) = \begin{pmatrix} .2358 & .7024 \\ .8105 & .8785 \end{pmatrix}$$

So $r_1{}^0 = .2358$ *and* $r_2{}^0 = .8105$

$$v_{ij}^{t+1} = v_{ij}^t + c_1 r_{1j}^t * \left[p_{best,i}^t - x_{ij}^t \right] + c_2 r_{2j}^t * \left[G_{best} - x_{ij}^t \right]$$

$t = 0$ and $i = 1$

$$v_1^1 = v_1^0 + c_1 r_1^0 * \left[p_{best,1}^0 - x_1^0 \right] + c_2 r_2^0 * \left[G_{best} - x_1^0 \right]$$

$$v_1^1 = 0 + 2 * .2358[0 - 0] + 2 * .8105[.4 - 0] = .6484$$

$$v_2^1 = .4863 \ , v_3^1 = .3242 \ , v_4^1 = .1621 \ , v_5^1 = 0 \ , v_6^1 = .8105 \ ,$$

$$v_7^1 = .9726 \quad v_8^1 = 1.1347 \ , v_9^1 = 1.2968$$

$$xi^{t+1} = xi^t + vi^{t+1}$$

$$x_1^1 = .6484 \ , x_2^1 = .5863 \ , x_3^1 = .5242 \ , x_4^1 = .4621, x_5^1 = .4$$

$$x_6^1 = .7105 \ , x_7^1 = .7726 \ , x_8^1 = .8347 \ , x_9^1 = .8968$$

then $f_1^1 = .11208264 \ , f_2^1 = .11179698 \ , f_3^1 = .1151132$

$f_4^1 = .11122566 \ f_5^1 = .11094 \ , f_6^1 = .1123683 \ , f_7^1 = .11265396$

$f_8^1 = .11293962, \ f_9^1 = .1132252$

$$p_{best,i}^{t+1} = \begin{cases} p_{best,i}^t & \text{if } f(x_i^{t+1}) > p_{best,i}^t \\ xi^{t+1} & \text{if } f(x_i^{t+1}) \le p_{best,i}^t \end{cases}$$

$p_{best,1}^1 = 0$ *because* $f_1^1 > p_{best,1}^0$

$p_{best,2}^1 = .1$ *because* $f_2^1 > p_{best,2}^0$

$$p^1_{best,3} = x^1_3 = .5242 \; because \; f^1_3 < p^0_{best,3}$$

$$p^1_{best,4} = x^1_4 = .4621 \; because \; f^1_4 < p^0_{best,4}$$

$$p^1_{best,5} = x^1_5 = .4 \; because \; f^1_5 < p^0_{best,5}$$

$$p^1_{best,6} = -.1 \ldots . f^1_6 > p^0_{best,6}$$

$$p^1_{best,7} = -.2 \ldots \ldots . . f^1_7 > p^0_{best,7}$$

$$p^1_{best,8} = -.3 \ldots \ldots f^1_8 > p^0_{best,8}$$

$$p^1_{best,9} = -.4 \ldots \ldots \ldots f^1_9 > p^0_{best,9}$$

$$r^1_1 = .7024 \& \quad r^1_2 = .8785$$

$$G_{best} = min\{.5242\} = .5242$$

$$v^2_1 = v^1_1 + c_1 r^1_1 * \left[p^1_{best,1} - x^1_1 \right] + c_2 r^1_2 * \left[G_{best} - x^1_1 \right]$$

$$.6484 + 2 * .7024[0 - .6484] + 2 * .8785[.5242 - .6484]$$

$$= -.48069172$$

$$v^2_2 = -.30596394 \, , v^2_3 = .3242 \, , v^2_4 = .2712097 \, , v^2_5 = .2182815$$

$$v^2_6 = -.65551265 \, , v^2_7 = -.83014728 \, , v^2_8 = -1.00487506$$

$$v^2_9 = -1.17960284$$

So

$x_1^2 = .16770826 \, , x_2^2 = .22033606 \, , x_3^2 = .8484$

$x_4^2 = .7333097 \, , x_5^2 = .6182815 \, , x_6^2 = .05498735$

$x_7^2 = -.05754728 \, , x_8^2 = -.17017506 \, , x_9^2 = -.28280284$

And we find f_i^t

$f_1^1 = .109871458 \, , f_2^1 = .110113545 \, , f_3^1 = .11300264$

$f_4^1 = .112473224, f_5^1 = .111944094 \, , f_6^1 = .109353941 \, ,$

$f_7^1 = .108835282 \, , f_8^1 = .108317194, f_9^1 = .10779898$

Stop because: -

We note that the value of f_i^2 is very close to the value of f_i^1

Particle Swarm Optimization is used in much nonlinear application because it has many advantages such as: can be simple to implement, can be robust, can converge fast, have short computational time can be efficient for solving problems presenting difficulty to find accurate mathematical models and have higher probability and efficiency in finding the global optima. But it has few disadvantages it can be difficult to define initial design parameters and can converge prematurely and be trapped into a local minimum especially with a complex problem.

When we applied PSO in to our data (predict in solar radiation) as we explained above, we reached this result:

 1-) the probability that the solar radiation on a specific day (at 10 am) will remain unchanged from the previous day is 0.109871458

2-) the probability that the solar radiation on a specific day (at 10 am) will increase by 0.1 from the previous day is 0.110113545

3-) the probability that the solar radiation on a specific day (at 10 am) will increase by 0.2 from the previous day is 0.1130026

4-) the probability that the solar radiation on a specific day (at 10 am) will increase by 0.3 from the previous day is   0.112473224

5-) the probability that the solar radiation on a specific day (at 10 am) will increase by 0.4 from the previous day is 0.111944094

 6-) the probability that the solar radiation on a specific day (at 10 am) will decrease by 0.1 from the previous day is 0.109352941

7-) the probability that the solar radiation on a specific day (at 10 am) will decrease by 0.2 from the previous day is 0.108835282

8-) The probability that the solar radiation on a specific day (at 10 am) will decrease by 0.3 from the previous day is 0.108317194

9-) the probability that the solar radiation on a specific day (at 10 am) will decrease by 0.4 from the previous day is 0.10779898

3.2.3 Markov Chains

-First, we take one value in a day (10 pm) from the data we have along a year.

-Second, we round each value nearest to the tenth.

-Third, we calculate the change between past and the present day.

-Fourth we applied the Markov chain in the MS Excel program

Table (3.3): All the value we need to apply Markov Chains.

P-STATES	Change from the previous day	round to .1	solar radiation	Date
		0.2	0.219	01/01/13
	0.1	0.3	0.254	02/01/13
$P_{.1,-.1}$	-0.1	0.2	0.218	03/01/13
$P_{-.1,0}$	0	0.2	0.23	04/01/13
$P_{0,0}$	0	0.2	0.22	05/01/13
$P_{0,-.2}$	-0.2	0	0.007	06/01/13
$P_{-.2,0}$	0	0	0.034	07/01/13
$P_{0,0}$	0	0	0.013	08/01/13
$P_{0,.1}$	0.1	0.1	0.13	09/01/13
$P_{.1,0}$	0	0.1	0.139	10/01/13
$P_{0,0}$	0	0.1	0.114	11/01/13

$P_{0,.1}$	0.1	0.2	0.177	12/01/13
$P_{.1,0}$	0	0.2	0.242	13/01/13
$P_{0,0}$	0	0.2	0.241	14/01/13
$P_{0,.1}$	0.1	0.3	0.256	15/01/13
$P_{.1,0}$	0	0.3	0.256	16/01/13
$P_{0,-.1}$	-0.1	0.2	0.214	17/01/13
$P_{-.1.1}$	0.1	0.3	0.263	18/01/13
$P_{.1,-.1}$	-0.1	0.2	0.22	19/01/13
$P_{-.1,0}$	0	0.2	0.235	20/01/13
$P_{0,.1}$	0.1	0.3	0.271	21/01/13
$P_{.1,-.1}$	-0.1	0.2	0.171	22/01/13
$P_{-.1,.1}$	0.1	0.3	0.26	23/01/13
$P_{.1,0}$	0	0.3	0.286	24/01/13
$P_{.1,0}$	-0.1	0.2	0.213	25/01/13
$P_{-.1,.1}$	0.1	0.3	0.258	26/01/13
$P_{.1,-.1}$	-0.1	0.2	0.217	27/01/13
$P_{-.1,0}$	0	0.2	0.223	28/01/13
$P_{0,-.1}$	-0.1	0.1	0.106	29/01/13
$P_{-.1,-.1}$	-0.1	0	0.044	30/01/13
$P_{-.1,0}$	0	0	0.029	31/01/13
$P_{0,.1}$	0.1	0.1	0.084	01/02/13
$P_{.1,.2}$	0.2	0.3	0.287	02/02/13
$P_{.2,0}$	0	0.3	0.304	03/02/13
$P_{0,0}$	0	0.3	0.313	04/02/13
$P_{0,-.1}$	-0.1	0.2	0.17	05/02/13
$P_{-.1,0}$	0	0.2	0.153	06/02/13
$P_{0,.1}$	0.1	0.3	0.271	07/02/13
$P_{.1,0}$	0	0.3	0.281	08/02/13
$P_{0,0}$	0	0.3	0.29	09/02/13

$P_{0,0}$	0	0.3	0.275	10/02/13
$P_{0,0}$	0	0.3	0.285	11/02/13
$P_{0,-.2}$	-0.2	0.1	0.127	12/02/13
$P_{-.2,.2}$	0.2	0.3	0.335	13/02/13
$P_{.2,-.2}$	-0.2	0.1	0.144	14/02/13
$P_{-.2,.1}$	0.1	0.2	0.24	15/02/13
$P_{.1,-.1}$	-0.1	0.1	0.131	16/02/13
$P_{-.1,.2}$	0.2	0.3	0.336	17/02/13
$P_{.2,.1}$	0.1	0.4	0.351	18/02/13
$P_{.1,-.1}$	-0.1	0.3	0.344	19/02/13
$P_{-.1,.1}$	0.1	0.4	0.352	20/02/13
$P_{.1,-.1}$	-0.1	0.3	0.346	21/02/13
$P_{-.1,0}$	0	0.3	0.319	22/02/13
$P_{0,-.1}$	-0.1	0.2	0.235	23/02/13
$P_{-.1,0}$	0	0.2	0.248	24/02/13
$P_{0,.1}$	0.1	0.3	0.273	25/02/13
$P_{.1,.1}$	0.1	0.4	0.386	26/02/13
$P_{.1,0}$	0	0.4	0.379	27/02/13
$P_{0,0}$	0	0.4	0.368	28/02/13
$P_{0,0}$	0	0.4	0.426	01/03/13
$P_{0,0}$	0	0.4	0.394	02/03/13
$P_{0,-.1}$	-0.1	0.3	0.305	03/03/13
$P_{-.1,0}$	0	0.3	0.291	04/03/13
$P_{0,.1}$	0.1	0.4	0.368	05/03/13
$P_{.1,0}$	0	0.4	0.425	06/03/13
$P_{0,0}$	0	0.4	0.411	07/03/13
$P_{0,0}$	0	0.4	0.404	08/03/13
$P_{0,0}$	0	0.4	0.381	09/03/13
$P_{0,0}$	0	0.4	0.375	10/03/13

$P_{0,0}$	0	0.4	0.403	11/03/13
$P_{0,0}$	0	0.4	0.419	12/03/13
$P_{0,0}$	0	0.4	0.42	13/03/13
$P_{0,0}$	0	0.4	0.437	14/03/13
$P_{0,0}$	0	0.4	0.427	15/03/13
$P_{0,-.1}$	-0.1	0.3	0.286	16/03/13
$P_{-.1,-.1}$	-0.1	0.2	0.214	17/03/13
$P_{-.1,.1}$	0.1	0.3	0.336	18/03/13
$P_{.1,0}$	0	0.3	0.331	19/03/13
$P_{0,.2}$	0.2	0.5	0.461	20/03/13
$P_{.2,0}$	0	0.5	0.49	21/03/13
$P_{0,0}$	0	0.5	0.497	22/03/13
$P_{0,-.3}$	-0.3	0.2	0.207	23/03/13
$P_{-.3,.3}$	0.3	0.5	0.549	24/03/13
$P_{.3,0}$	0	0.5	0.51	25/03/13
$P_{0,-.1}$	-0.1	0.4	0.429	26/03/13
$P_{-.1,0}$	0	0.4	0.415	27/03/13
$P_{0,-.1}$	-0.1	0.3	0.345	28/03/13
$P_{-.1,.2}$	0.2	0.5	0.515	29/03/13
$P_{.2,0}$	0	0.5	0.504	30/03/13
$P_{0,0}$	0	0.5	0.456	31/03/13
$P_{0,-.1}$	-0.1	0.4	0.425	01/04/13
$P_{-.1,0}$	0	0.4	0.422	02/04/13
$P_{0,.1}$	0.1	0.5	0.54	03/04/13
$P_{.1,-.1}$	-0.1	0.4	0.354	04/04/13
$P_{-.1,0}$	0	0.4	0.363	05/04/13
$P_{0,.1}$	0.1	0.5	0.493	06/04/13
$P_{.1,0}$	0	0.5	0.488	07/04/13
$P_{0,-.1}$	-0.1	0.4	0.385	08/04/13

$P_{-.1,-.2}$	-0.2	0.2	0.234	09/04/13
$P_{-.2,.2}$	0.2	0.4	0.354	10/04/13
$P_{.2,-.1}$	-0.1	0.3	0.346	11/04/13
$P_{-.1,.2}$	0.2	0.5	0.483	12/04/13
$P_{.2,-.3}$	-0.3	0.2	0.184	13/04/13
$P_{-.3,.4}$	0.4	0.6	0.568	14/04/13
$P_{.4,0}$	0	0.6	0.586	15/04/13
$P_{0,-.4}$	-0.4	0.2	0.169	16/04/13
$P_{-.4,-.1}$	-0.1	0.1	0.111	17/04/13
$P_{-.1,.2}$	0.2	0.3	0.253	18/04/13
$P_{.2,0}$	0	0.3	0.271	19/04/13
$P_{0,-.3}$	-0.3	0	0.035	20/04/13
$P_{-.3,.1}$	0.1	0.1	0.077	21/04/13
$P_{.1,.4}$	0.4	0.5	0.476	22/04/13
$P_{.4,0}$	0	0.5	0.507	23/04/13
$P_{0,.1}$	0.1	0.6	0.602	24/04/13
$P_{.1,0}$	0	0.6	0.612	25/04/13
$P_{0,0}$	0	0.6	0.622	26/04/13
$P_{0,0}$	0	0.6	0.619	27/04/13
$P_{0,0}$	0	0.6	0.604	28/04/13
$P_{0,0}$	0	0.6	0.616	29/04/13
$P_{0,0}$	0	0.6	0.608	30/04/13
$P_{0,-.1}$	-0.1	0.5	0.453	01/05/13
$P_{-.1,0}$	0	0.5	0.521	02/05/13
$P_{0,.1}$	0.1	0.6	0.569	03/05/13
$P_{.1,0}$	0	0.6	0.587	04/05/13
$P_{0,0}$	0	0.6	0.587	05/05/13
$P_{0,0}$	0	0.6	0.58	06/05/13
$P_{0,-.1}$	-0.1	0.5	0.536	07/05/13

$P_{-.1,.1}$	0.1	0.6	0.612	08/05/13
$P_{.1,-.3}$	-0.3	0.3	0.313	09/05/13
$P_{-.3,.3}$	0.3	0.6	0.603	10/05/13
$P_{.3,-.2}$	-0.2	0.4	0.389	11/05/13
$P_{-.2,0}$	0	0.4	0.352	12/05/13
$P_{0,.2}$	0.2	0.6	0.622	13/05/13
$P_{.2,-.2}$	-0.2	0.4	0.372	14/05/13
$P_{-.2,-.2}$	-0.2	0.2	0.184	15/05/13
$P_{-.2,.3}$	0.3	0.5	0.512	16/05/13
$P_{.3,-.1}$	-0.1	0.4	0.411	17/05/13
$P_{-.1,.1}$	0.1	0.5	0.485	18/05/13
$P_{.1,0}$	0	0.5	0.522	19/05/13
$P_{0,.1}$	0.1	0.6	0.577	20/05/13
$P_{.1,0}$	0	0.6	0.608	21/05/13
$P_{0,0}$	0	0.6	0.625	22/05/13
$P_{0,0}$	0	0.6	0.636	23/05/13
$P_{0,0}$	0	0.6	0.61	24/05/13
$P_{0,-.1}$	-0.1	0.5	0.536	25/05/13
$P_{-.1,-.1}$	-0.1	0.4	0.425	26/05/13
$P_{-.1,.2}$	0.2	0.6	0.574	27/05/13
$P_{.2,0}$	0	0.6	0.612	28/05/13
$P_{0,0}$	0	0.6	0.624	29/05/13
$P_{0,0}$	0	0.6	0.586	30/05/13
$P_{0,0}$	0	0.6	0.603	31/05/13
$P_{0,0}$	0	0.6	0.602	01/06/13
$P_{0,0}$	0	0.6	0.601	02/06/13
$P_{0,0}$	0	0.6	0.572	03/06/13
$P_{0,0}$	0	0.6	0.611	04/06/13
$P_{0,0}$	0	0.6	0.606	05/06/13

$P_{0,0}$	0	0.6	0.623	06/06/13
$P_{0,-.4}$	-0.4	0.2	0.215	07/06/13
$P_{-.4,.3}$	0.3	0.5	0.484	08/06/13
$P_{.3,-.1}$	-0.1	0.4	0.447	09/06/13
$P_{-.1,.1}$	0.1	0.5	0.471	10/06/13
$P_{.1,.1}$	0.1	0.6	0.603	11/06/13
$P_{.1,0}$	0	0.6	0.618	12/06/13
$P_{0,-.1}$	-0.1	0.5	0.484	13/06/13
$P_{-.1,0}$	0	0.5	0.509	14/06/13
$P_{0,0}$	0	0.5	0.453	15/06/13
$P_{0,0}$	0	0.5	0.542	16/06/13
$P_{0,0}$	0	0.5	0.529	17/06/13
$P_{0,0}$	0	0.5	0.535	18/06/13
$P_{0,.1}$	0.1	0.6	0.6	19/06/13
$P_{.1,0}$	0	0.6	0.598	20/06/13
$P_{0,0}$	0	0.6	0.599	21/06/13
$P_{0,-.2}$	-0.2	0.4	0.429	22/06/13
$P_{-.2,.2}$	0.2	0.6	0.572	23/06/13
$P_{.2,0}$	0	0.6	0.6	24/06/13
$P_{0,0}$	0	0.6	0.55	25/06/13
$P_{0,0}$	0	0.6	0.601	26/06/13
$P_{0,0}$	0	0.6	0.609	27/06/13
$P_{0,0}$	0	0.6	0.623	28/06/13
$P_{0,-.2}$	-0.2	0.4	0.37	29/06/13
$P_{-.2,.1}$	0.1	0.5	0.454	30/06/13
$P_{.1,-.1}$	-0.1	0.4	0.448	01/07/13
$P_{-.1,.1}$	0.1	0.5	0.492	02/07/13
$P_{.1,0}$	0	0.5	0.535	03/07/13
$P_{0,.1}$	0.1	0.6	0.606	04/07/13

$P_{-1,0}$	0	0.6	0.633	05/07/13
$P_{0,0}$	0	0.6	0.564	06/07/13
$P_{0,0}$	0	0.6	0.585	07/07/13
$P_{0,0}$	0	0.6	0.587	08/07/13
$P_{0,0}$	0	0.6	0.59	09/07/13
$P_{0,-2}$	-0.2	0.4	0.403	10/07/13
$P_{-2,0}$	0	0.4	0.395	11/07/13
$P_{0,0}$	0	0.4	0.433	12/07/13
$P_{0,0}$	0	0.4	0.4	13/07/13
$P_{0,.1}$	0.1	0.5	0.465	14/07/13
$P_{-1,.1}$	0.1	0.6	0.563	15/07/13
$P_{-1,-.1}$	-0.1	0.5	0.545	16/07/13
$P_{-.1-.1}$	-0.1	0.4	0.442	17/07/13
$P_{-.1,.1}$	0.1	0.5	0.493	18/07/13
$P_{-1,-.1}$	-0.1	0.4	0.411	19/07/13
$P_{-.1,.1}$	0.1	0.5	0.482	20/07/13
$P_{-1,0}$	0	0.5	0.539	21/07/13
$P_{0,0}$	0	0.5	0.478	22/07/13
$P_{0,.1}$	0.1	0.6	0.57	23/07/13
$P_{-1,0}$	0	0.6	0.561	24/07/13
$P_{0,-.1}$	-0.1	0.5	0.495	25/07/13
$P_{-.1,0}$	0	0.5	0.467	26/07/13
$P_{0,0}$	0	0.5	0.495	27/07/13
$P_{0,.1}$	0.1	0.6	0.557	28/07/13
$P_{-1,0}$	0	0.6	0.567	29/07/13
$P_{0,-.1}$	-0.1	0.5	0.497	30/07/13
$P_{-.1,0}$	0	0.5	0.543	31/07/13
$P_{0,0}$	0	0.5	0.489	01/08/13
$P_{0,.1}$	0.1	0.6	0.569	02/08/13

$P_{.1,-.1}$	-0.1	0.5	0.489	03/08/13
$P_{-.1,0}$	0	0.5	0.477	04/08/13
$P_{0,0}$	0	0.5	0.466	05/08/13
$P_{0,0}$	0	0.5	0.507	06/08/13
$P_{0,.1}$	0.1	0.6	0.56	07/08/13
$P_{.1,0}$	0	0.6	0.582	08/08/13
$P_{0,0}$	0	0.6	0.578	09/08/13
$P_{0,0}$	0	0.6	0.582	10/08/13
$P_{0,-.1}$	-0.1	0.5	0.546	11/08/13
$P_{-.1,.1}$	0.1	0.6	0.572	12/08/13
$P_{.1,-.1}$	-0.1	0.5	0.523	13/08/13
$P_{-.1,.1}$	0.1	0.6	0.565	14/08/13
$P_{.1,-.2}$	-0.2	0.4	0.417	15/08/13
$P_{-.2,.1}$	0.1	0.5	0.522	16/08/13
$P_{.1,-.1}$	-0.1	0.4	0.438	17/08/13
$P_{-.1,.1}$	0.1	0.5	0.46	18/08/13
$P_{.1,.1}$	0.1	0.6	0.569	19/08/13
$P_{.1,0}$	0	0.6	0.57	20/08/13
$P_{0,0}$	0	0.6	0.579	21/08/13
$P_{0,0}$	0	0.6	0.559	22/08/13
$P_{0,0}$	0	0.6	0.575	23/08/13
$P_{0,0}$	0	0.6	0.5551	24/08/13
$P_{0,0}$	0	0.6	0.569	25/08/13
$P_{0,0}$	0	0.6	0.552	26/08/13
$P_{0,-.1}$	-0.1	0.5	0.502	27/08/13
$P_{-.1,0}$	0	0.5	0.54	28/08/13
$P_{0,0}$	0	0.5	0.473	29/08/13
$P_{0,0}$	0	0.5	0.543	30/08/13
$P_{0,0}$	0	0.5	0.484	31/08/13

$P_{0,-.1}$	-0.1	0.4	0.42	01/09/13
$P_{-.1,.1}$	0.1	0.5	0.539	02/09/13
$P_{.1,0}$	0	0.5	0.525	03/09/13
$P_{0,0}$	0	0.5	0.522	04/09/13
$P_{0,0}$	0	0.5	0.516	05/09/13
$P_{0,0}$	0	0.5	0.528	06/09/13
$P_{0,0}$	0	0.5	0.523	07/09/13
$P_{0,0}$	0	0.5	0.475	08/09/13
$P_{0,-.1}$	-0.1	0.4	0.373	09/09/13
$P_{-.1,.1}$	0.1	0.5	0.45	10/09/13
$P_{.1,0}$	0	0.5	0.529	11/09/13
$P_{0,0}$	0	0.5	0.509	12/09/13
$P_{0,0}$	0	0.5	0.459	13/09/13
$P_{0,0}$	0	0.5	0.522	14/09/13
$P_{0,0}$	0	0.5	0.509	15/09/13
$P_{0,0}$	0	0.5	0.501	16/09/13
$P_{0,-.1}$	-0.1	0.4	0.449	17/09/13
$P_{-.1,0}$	0	0.4	0.438	18/09/13
$P_{0,0}$	0	0.4	0.396	19/09/13
$P_{0,.1}$	0.1	0.5	0.474	20/09/13
$P_{.1,0}$	0	0.5	0.484	21/09/13
$P_{0,-.1}$	-0.1	0.4	0.383	22/09/13
$P_{-.1,.1}$	0.1	0.5	0.48	23/09/13
$P_{.1,0}$	0	0.5	0.5	24/09/13
$P_{0,0}$	0	0.5	0.494	25/09/13
$P_{0,0}$	0	0.5	0.505	26/09/13
$P_{0,0}$	0	0.5	0.494	27/09/13
$P_{0,0}$	0	0.5	0.453	28/09/13
$P_{0,-.2}$	-0.2	0.3	0.287	29/09/13

$P_{-.2,.1}$	0.1	0.4	0.407	30/09/13
$P_{.1,-.1}$	-0.1	0.3	0.302	01/10/13
$P_{-.1,0}$	0	0.3	0.342	02/10/13
$P_{0,.1}$	0.1	0.4	0.412	03/10/13
$P_{.1,-.1}$	-0.1	0.3	0.336	04/10/13
$P_{-.1,.2}$	0.2	0.5	0.454	05/10/13
$P_{.2,-.1}$	-0.1	0.4	0.425	06/10/13
$P_{-.1,.1}$	0.1	0.5	0.458	07/10/13
$P_{.1,0}$	0	0.5	0.475	08/10/13
$P_{0,0}$	0	0.5	0.451	09/10/13
$P_{0,0}$	0	0.5	0.459	10/10/13
$P_{0,0}$	0	0.5	0.471	11/10/13
$P_{0,-.2}$	-0.2	0.3	0.274	12/10/13
$P_{-.2,.1}$	0.1	0.4	0.44	13/10/13
$P_{.1,0}$	0	0.4	0.443	14/10/13
$P_{0,0}$	0	0.4	0.433	15/10/13
$P_{0,0}$	0	0.4	0.415	16/10/13
$P_{0,-.1}$	-0.1	0.3	0.294	17/10/13
$P_{-.1,-.1}$	-0.1	0.2	0.155	18/10/13
$P_{-.1,.2}$	0.2	0.4	0.405	19/10/13
$P_{.2,-.1}$	-0.1	0.3	0.347	20/10/13
$P_{-.1,0}$	0	0.3	0.279	21/10/13
$P_{0,.1}$	0.1	0.4	0.391	22/10/13
$P_{.1,0}$	0	0.4	0.385	23/10/13
$P_{0,-.2}$	-0.2	0.2	0.237	24/10/13
$P_{-.2,.2}$	0.2	0.4	0.4	25/10/13
$P_{.2,-.2}$	-0.2	0.2	0.154	26/10/13
$P_{-.2,.2}$	0.2	0.4	0.363	27/10/13
$P_{.2,0}$	0	0.4	0.414	28/10/13

$P_{0,0}$	0	0.4	0.402	29/10/13
$P_{0,0}$	0	0.4	0.387	30/10/13
$P_{0,0}$	0	0.4	0.376	31/10/13
$P_{0,0}$	0	0.4	0.35	01/11/13
$P_{0,-.1}$	-0.1	0.3	0.3	02/11/13
$P_{-.1,0}$	0	0.3	0.316	03/11/13
$P_{0,0}$	0	0.3	0.281	04/11/13
$P_{0,0}$	0	0.3	0.289	05/11/13
$P_{0,0}$	0	0.3	0.261	06/11/13
$P_{0,0}$	0	0.3	0.346	07/11/13
$P_{0,.1}$	0.1	0.4	0.354	08/11/13
$P_{.1,-.1}$	-0.1	0.3	0.251	09/11/13
$P_{-.1,-.1}$	-0.1	0.2	0.197	10/11/13
$P_{-.1,0}$	0	0.2	0.204	11/11/13
$P_{0,0}$	0	0.2	0.155	12/11/13
$P_{0,.2}$	0.2	0.4	0.35	13/11/13 10:00
$P_{.2,-.1}$	-0.1	0.3	0.34	14/11/13 10:00
$P_{-.1,0}$	0	0.3	0.349	15/11/13
$P_{0,0}$	0	0.3	0.338	16/11/13
$P_{0,0}$	0	0.3	0.302	17/11/13
$P_{0,0}$	0	0.3	0.299	18/11/13
$P_{0,0}$	0	0.3	0.29	19/11/13
$P_{0,0}$	0	0.3	0.307	20/11/13
$P_{0,0}$	0	0.3	0.283	21/11/13
$P_{0,0}$	0	0.3	0.286	22/11/13
$P_{0,-.2}$	-0.2	0.1	0.074	23/11/13
$P_{-.2,0}$	0	0.1	0.078	24/11/13

$P_{0,0}$	0	0.1	0.093	25/11/13
$P_{0,.2}$	0.2	0.3	0.304	26/11/13
$P_{.2,-.2}$	-0.2	0.1	0.057	27/11/13
$P_{-.2,.2}$	0.2	0.3	0.301	28/11/13
$P_{.2,0}$	0	0.3	0.323	29/11/13
$P_{0,-.1}$	-0.1	0.2	0.198	30/11/13
$P_{-.1,.1}$	0.1	0.3	0.296	01/12/13
$P_{.1,-.1}$	-0.1	0.2	0.22	02/12/13
$P_{-.1,.1}$	0.1	0.3	0.292	03/12/13
$P_{.1,-.1}$	-0.1	0.2	0.209	04/12/13
$P_{-.1,.1}$	0.1	0.3	0.261	05/12/13
$P_{.1,-.1}$	-0.1	0.2	0.226	06/12/13
$P_{-.1,0}$	0	0.2	0.221	07/12/13
$P_{0,0}$	0	0.2	0.157	08/12/13
$P_{0,-.1}$	-0.1	0.1	0.106	09/12/13
$P_{-.1,.2}$	0.2	0.3	0.274	10/12/13
$P_{.2,-.1}$	-0.1	0.2	0.195	11/12/13
$P_{-.1,0}$	0	0.2	0.225	12/12/13
$P_{0,-.1}$	-0.1	0.1	0.083	13/12/13
$P_{-.1,.1}$	0.1	0.2	0.176	14/12/13
$P_{.1,.1}$	0.1	0.3	0.267	15/12/13
$P_{.1,-.1}$	-0.1	0.2	0.208	16/12/13
$P_{-.1,.1}$	0.1	0.3	0.26	17/12/13
$P_{.1,0}$	0	0.3	0.252	18/12/13
$P_{0,0}$	0	0.3	0.252	19/12/13
$P_{0,-.2}$	-0.2	0.1	0.109	20/12/13
$P_{-.2,0}$	0	0.1	0.122	21/12/13
$P_{0,0}$	0	0.1	0.13	22/12/13
$P_{0,.2}$	0.2	0.3	0.25	23/12/13

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$P_{.2,0}$	0	0.3	0.254	24/12/13
$P_{0,-.1}$	-0.1	0.2	0.166	25/12/13
$P_{-.1,-.1}$	-0.1	0.1	0.103	26/12/13
$P_{-.1,.1}$	0.1	0.2	0.239	27/12/13
$P_{.1,0}$	0	0.2	0.24	28/12/13
$P_{0,0}$	0	0.2	0.231	29/12/13
$P_{0,0}$	0	0.2	0.231	30/12/13
$P_{0,0}$	0	0.2	0.234	31/12/13

5-Calculate the states [we have 9 stats (0, .1, .2, .3, .4,-.1,-.2,-.3,-.4)]

Table (3.4): From one state to another is tabulated as below.

	0	.1	.2	.3	.4	-.1	-.2	-.3	-.4	Total
0	115	24	5	-	-	28	10	2	2	186
.1	31	5	1	-	-	21	1	1	-	60
.2	9	1	-	1	-	5	4	1	-	21
.3	2	-	-	-	-	1	-	-	-	3
.4	1	-	2	1	-	-	-	-	-	4
-.1	25	24	8	-	-	7	1	-	-	65
-.2	5	5	6	1	-	-	1	-	-	118
-.3	-	-	-	2	1	-	-	-	-	4
-.4	-	-	-	1	-	1	-	-	-	2

Now we find the steady states by applying the following equation

$$\Pi * P = \Pi$$

$$
\mathbf{p} =
\begin{bmatrix}
\dfrac{115}{186} & \dfrac{24}{186} & \dfrac{5}{186} & 0 & 0 & \dfrac{28}{186} & \dfrac{10}{186} & \dfrac{2}{186} & \dfrac{2}{186} \\[2mm]
\dfrac{31}{60} & \dfrac{5}{60} & \dfrac{1}{60} & 0 & 0 & \dfrac{21}{60} & \dfrac{1}{60} & \dfrac{1}{60} & 0 \\[2mm]
\dfrac{9}{21} & \dfrac{1}{21} & 0 & \dfrac{1}{21} & 0 & \dfrac{5}{12} & \dfrac{4}{12} & \dfrac{1}{12} & 0 \\[2mm]
\dfrac{2}{3} & 0 & 0 & 0 & 0 & \dfrac{1}{3} & 0 & 0 & 0 \\[2mm]
\dfrac{1}{4} & 0 & \dfrac{2}{4} & \dfrac{1}{4} & 0 & 0 & 0 & 0 & 0 \\[2mm]
\dfrac{25}{65} & \dfrac{24}{65} & \dfrac{8}{65} & 0 & 0 & \dfrac{7}{65} & \dfrac{1}{65} & 0 & 0 \\[2mm]
\dfrac{5}{18} & \dfrac{5}{18} & \dfrac{6}{18} & \dfrac{1}{18} & 0 & 0 & \dfrac{1}{18} & 0 & 0 \\[2mm]
0 & \dfrac{1}{4} & 0 & \dfrac{2}{4} & \dfrac{1}{4} & 0 & 0 & 0 & 0 \\[2mm]
0 & 0 & 0 & \dfrac{1}{2} & 0 & \dfrac{1}{2} & 0 & 0 & 0
\end{bmatrix}
$$

Where:

$$[\Pi1\ \Pi2\ \Pi3\ \Pi4\ \ldots \ldots\ \Pi9] * p = [\Pi1\ \Pi2\ \Pi3\ \Pi4\ \ldots .\ \Pi9]$$

By Matlab:

Let's say you have some Markov transition matrix, P.

We know that at steady state, there is some row vector$M$, such that $M * P = M$. We can recover that vector from the eigenvector of M' that corresponds to a unit eigenvalue.

Eig(P')

[V,D]=eig(P');
M=V(:,1)'
M=M./SUM(M)
*U=M*P*
*I=U*P*

```
P=[115/186 24/186 5/186 0 0 28/186 10/186 2/186 2/186
   31/60 5/60 1/60 0 0 21/60 1/60 1/60 0
   9/21 1/21 0 1/21 0 5/21 4/21 1/21 0
   2/3 0 0 0 0 1/3 0 0 0
   1/4 0 2/4 1/4 0 0 0 0 0
   25/65 24/65 8/65 0 0 7/65 1/65 0 0
   5/18 5/18 6/18 1/18 0 0 1/18 0 0
   0 1/4 0 2/4 1/4 0 0 0 0
   0 0 0 1/2 0 1/2 0 0 0];
eig(P');
[V,D]=eig(P');
M=V(:,1)';
M=M./sum(M)
U=M*P
I=U*P
```

Figure 3.8: the code after applied in Matlab

```
>> Untitled2

P =

    0.5233    0.1647    0.0555    0.0142    0.0028    0.1762    0.0468    0.0110    0.0056

U =

    0.5233    0.1647    0.0555    0.0142    0.0028    0.1762    0.0468    0.0110    0.0056

I =

    0.5233    0.1647    0.0555    0.0142    0.0028    0.1762    0.0468    0.0110    0.0056

fx >>
```

Figure 3.9: The result after applied code in Matlab

So $\Pi 1 = .5205$, $\Pi 2 = .1604$, $\Pi 3 = .0881$, $\Pi 4 = .0250$, $\Pi 5 = .0029$

$\Pi 6 = .1612$, $\Pi 7 = .0577$, $\Pi 8 = .012\ 1$, $\Pi 9 = .0054$.

now we calculate Π1+Π2+………Π9 and it equal 1.0001 it must be 1, so we change the format in matlab to have just 1.

Format short	1.0001
Format long	0.999999999
Format short e	1.0000024
Format long e	0.999076733
Format short g	1.0000024
Format long g	0.999999999
Format compact	0.999999999
Format loose	0.999999999
Format bank	1

And I want to make sure that when I multiply $(\Pi * p)$ will equal (Π) and it's clear ($I = U * P$ in Matlab) in figure (2.4.3)

Markov Chains is the best method to predict for long run:

$$
\lim_{n \to \infty} p^n = \begin{bmatrix} \Pi1 & \Pi2 & \Pi3 & . & . & . & . & . & \Pi9 \\ \Pi1 & . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . & . \\ \Pi1 & \Pi2 & \Pi3 & . & . & . & . & . & \Pi9 \end{bmatrix}
$$

For n$\geq$ 13 ,p^n consists of identical rows, each row is Π, that means the effect of the initial state disappears after 13 steps.

Markov chain method is a special method in prediction duo to predict for a long time in future, we reach too many results they are:

1-) The probability that the solar radiation at a specific day (in10am) will remain unchanged from the previous day is 0.5205

2-) The probability that the solar radiation on a specific day (at 10 am) will increase by 0.1 from the previous day is 0.1604

3-) The probability that the solar radiation on a specific day (at 10 am) will increase by 0.2 from the previous day is 0.0881

4-) The probability that the solar radiation on a specific day (at 10 am) will increase by 0.3 from the previous day is   0.0250

5-) The probability that the solar radiation on a specific day (at 10 am) will increase by 0.4 from the previous day is 0.029

 6-) The probability that the solar radiation on a specific day (at 10 am) will decrease by 0.1 from the previous day is 0.1612

7-) The probability that the solar radiation on a specific day (at 10 am) will decrease by 0.2 from the previous day is 0.0577

8-) The probability that the solar radiation on a specific day (at 10 am) will decrease by 0.3 from the previous day is 0.0121

9-) The probability that the solar radiation on a specific day (at 10 am) will decrease by 0.4 from the previous day is 0.054

Chapter Four

Comparison, Conclusion, and Results

In this chapter, we want to emphasize on the best method that has the best prediction and best result.

Take September as an example to focus on, I take all data at 10:00AM every day (all steps we do to Sep is applied for all months in the year)

Table (4.1): The data in (Aug & Sep) for two year (2012, 2013).

10:00/Aug & Sep/2012	10:00/Aug & Sep/2013
0.489	0.558
0.569	0.542
0.489	0.446
0.477	0.31
0.466	0.469
0.507	0.527
0.56	0.537
0.582	0.467
0.578	0.499
0.582	0.531
0.546	0.449
0.572	0.479
0.523	0.391
0.565	0.438

0.417	0.541
0.522	0.448
0.438	0.547
0.46	0.541
0.569	0.559
0.57	0.538
0.579	0.434
0.559	0.451
0.575	0.481
0.551	0.421
0.569	0.55
0.552	0.465
0.502	0.526
0.54	0.449
0.473	0.46
0.54	0.52
0.484	0.531
.42	.481
.539	.548
.525	.432
.522	.47
.516	.471
.528	.532
.523	.521

.475	.438
.373	.449
.45	.51
.529	.506
.509	.492
.459	.492
.522	.497
.509	.41
.501	.393
.448	.499
.438	.475
.396	.426
.474	.361
.484	.41
.383	.497
.48	.45
.5	.31
.494	.483
.505	.485
.494	.41
.453	.382
.287	.476
.407	.468

-Round all value for part of tenth (.1)

Table (4.2): The data after rounding.

2012	2013	Change
0.5	0.6	+.1
0.6	0.5	-0.1
0.5	0.5	0
0.5	0.3	-0.2
0.5	0.5	0
0.5	0.5	0
0.6	0.5	-0.1
0.6	0.5	-0.1
0.6	0.5	-0.1
0.6	0.5	-0.1
0.5	0.4	-0.1
0.6	0.5	-0.1
0.5	0.4	-0.1
0.6	0.4	-0.2
0.4	0.5	+0.1
0.5	0.5	0
0.4	0.5	+0.1
0.5	0.5	0
0.6	0.6	0
0.6	0.5	-0.1

0.6	0.4	-0.2
0.6	0.5	-0.1
0.6	0.5	-0.1
0.6	0.4	-0.2
0.6	0.6	0
0.6	0.5	-0.1
0.5	0.5	0
0.5	0.5	0
0.5	0.5	0
0.5	0.5	0
0.5	0.5	0
.4	.5	+.1
.5	.5	0
.5	.4	-.1
.5	.5	0
.5	.5	0
.5	.5	0
.5	.5	0
.5	.4	-.1
.4	.4	0
.5	.5	0
.5	.5	0
.5	.5	0
.5	.5	0

.5	.5	0
.5	.5	0
.5	.4	-.1
.5	.5	0
.4	.5	+.1
.4	.4	0
.5	.4	-.1
.5	.4	-.1
.4	.5	+.1
.5	.5	0
.5	.3	-.2
.5	.5	0
.5	.5	0
.5	.4	-.1
.5	.4	-.1
.3	.5	+.2
.4	.5	+.1

29/61 (0 that are not changing) =0.48333333

7/61(+.1 that are increasing by .1) =0.11475098

19/61(-.1 that are decreasing by .1) =0.311475409

1/61(+.2 is increasing by .2) =0.016393442

5/61(-.2 is decreasing by .2) =0.081967213
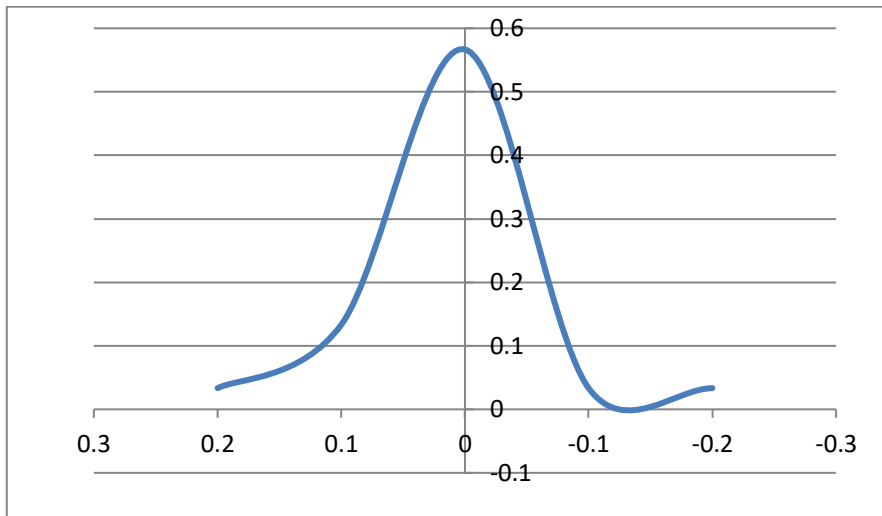
Figure 4.1: The relation between the changing in solar radiation and the prediction by using Markov Chain at 10:00 AM.
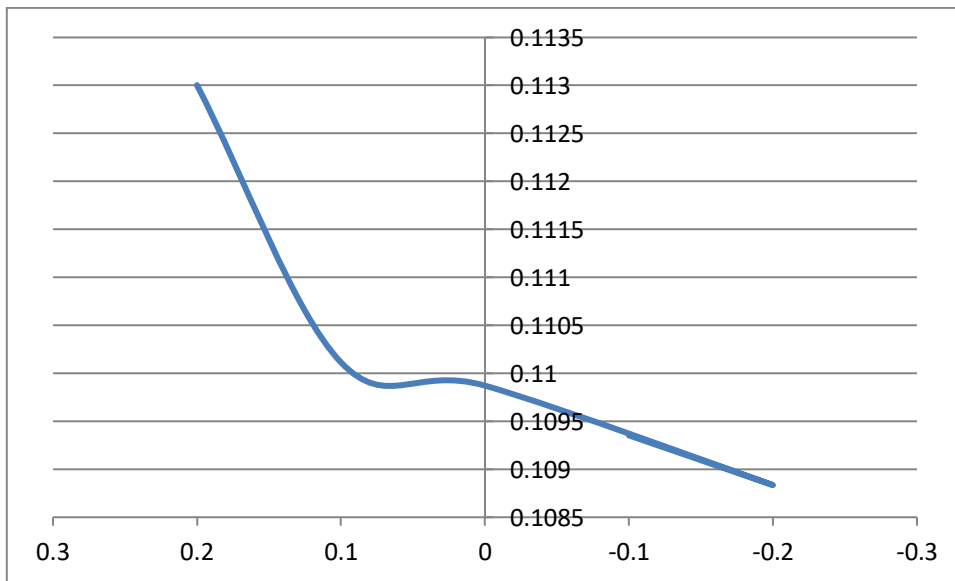
Figure 4.2: The relation between the changing in solar radiation and the prediction by using the nonlinear Particle Swarm Optimization at

10:00 AM.
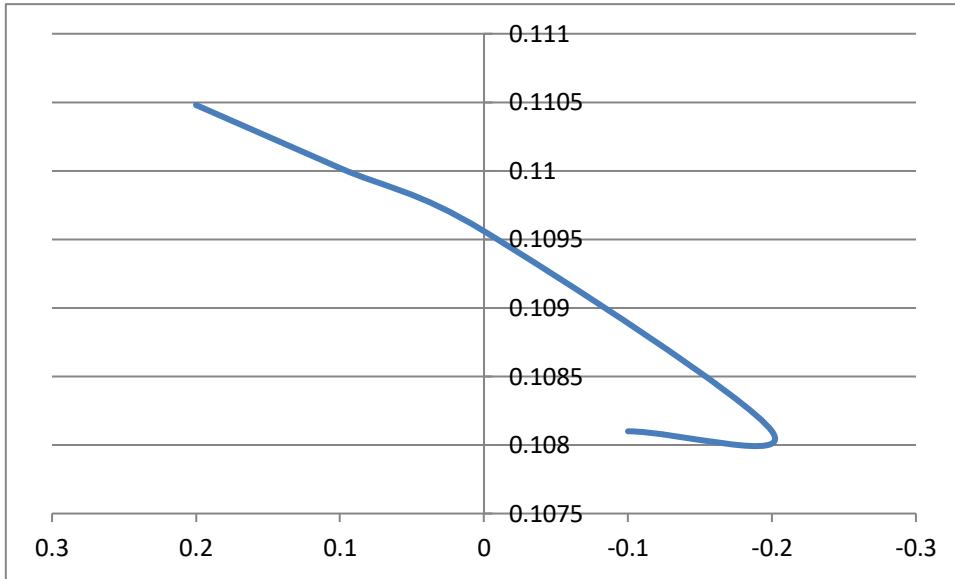
Figure 4.3:The relation between the changing in solar radiation and the prediction by using the nonlinear Simulated Annealing at 10:00 AM.
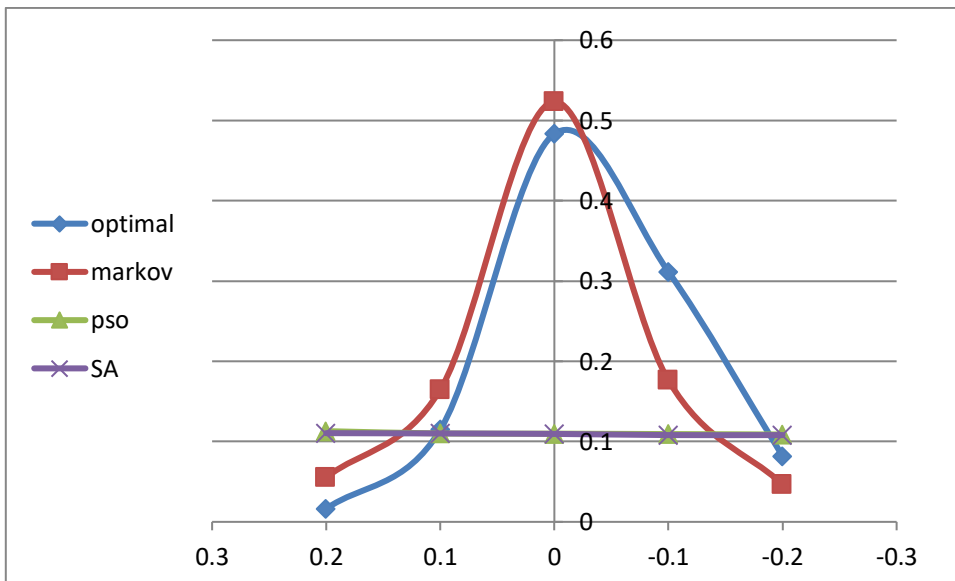
Figure 4.4: The relation between the changing in solar radiation (by in -0.2,-0.1, 0, 0.1, and 0.2) and the prediction by the three methods (Markov, SA, PSO) and the real value, as we seeing in the figure that Markov Chain is the best prediction method (it's very closed from the real).

Conclusion:

When we make the comparison, we note that:

1-In Markov chain method probability that is not changing =.5233 and it's near from real data (0.48333333), that are increasing .1 in Markov=.1647 it's near from real data (0.11475098), that are increasing .2 in Markov=.0555 and it's near from real data (0.01639344), that is decreasing .1 in Markov=.1762 and it's near from real data (0.311475409) and that is decreasing .2 in Markov=.0468 and it's near from real data (0.081967213) (Markov chain is the best method in prediction and its predict for a long time)

2-Partical Swarm Optimization (PSO) method probability that is not changing =.109871458 and it's not near from real data measurements (0.48333333), that are increasing .1 in PSO=.110113545 it's near from real data (0.11475098), that are increasing .2 in PSO=.11300264 and its not near from real data (0.016393442), that are decreasing .1 in PSO=.109352941 and its not near from real data (0.311475409) and that are decreasing .2 in PSO=.108835282 and its not near from real data (0.081967213)

3-Simulated Annealing (SA) method Probability that is not changing =.10956 and it's not near from real data (0.48333333), that are increasing .1 in SA=.110112 it is near from real data (0.11475098), that are increasing .2

in SA=.11048 and it's not near from real data (0.016393442), that is decreasing .1 in SA=.1081 and it's not near from real data (0.311475409) and that is decreasing .2 in SA=.1081 and it's not near from real data (0.081967213).

Table (4.3): shows the comparison between the optimal result and all methods.

Changing	Optimal	Markov	PSO	SA
-0.2	0.081967213	0.0468	0.18835282	0.1081
-0.1	0.311475409	0.1762	0.109352941	0.1081
0	0.48333333	0.5233	0.109871458	0.10956
+0.1	0.11475098	0.1647	0.110113545	0.110112
+0.2	0.016393442	0.0555	0.11300264	0.11048

After all we do, we noticed from table (4.3) and figure (4.4) that Markov chains is the best method in prediction solar energy in Palestine.

References

[1] Angström A., (1924), Solar terrestrial radiation. Quarterly Journal of the Royal Meteorological Society, Vol.6 No.3, 50:121–126, Brazilian.

[2] Blocho M., 2020, Heuristics, metaheuristics, and hyperheuristics for rich vehicle routing problems in Smart Delivery Systems, International Encyclopedia of the Social & Behavioral Sciences.

[3] Chala1 An A., Gemeda B A., 2018, Estimating Global Solar Radiation in Bale Robe Town Using Angstrom-Prescott and Hargreaves-Samani Models, College of Natural and Computational Science, Vol.8, (Paper) 16, Ethiopia.

[4] Das, Abraham A., and Konar, 2008, a Particle Swarm Optimization and Differential Evolution Algorithms: Technical Analysis, Applications and Hybridization Perspectives, Department of Electronics and Telecommunication Engineering, Jadavpur University, Kolkata 700032, India.

[5] Dorigo M., Maniezzo V., Colorni A., 1996, The Ant System: Optimization by a colony of cooperating agents, Member, IEEE, Vol.26, No.1.

[6] Eriksen J Th., Templafy C., 2018, General Data Protection Regulation.

[7] Freeman J., 2021, Scenario Planning Examples,

https://www.edrawsoft.com/scenario-planning-examples.html.

[8] Freitas D., Lopes L G., Dias F M., 2020, Particle Swarm Optimisation: A Historical Review Up to the Current Developments, Faculty of Exact Sciences and Engineering, University of Madeira, Penteada Campus, 9020-105 Vol.22(3), Funchal, Portugal.

[9] Henderson D., Jacobson S H., A W Johson., (April 2006), The Theory and Practice of Simulated Annealing, Hand book of Metaheuistic (pp.287-319), supported in part by the Air Force Office of Scientific Research (F49620-01-1-0007) and the National Science Foundation (DMI-9907980).

[10] Ismail. M. S, (2013), Energy Conversion and Management 73, Published, 57-68, Department of Electrical Engineering University of Malaysia, 50603 Kuala Lumpur, Malaysia.

[11] Kamarudin. A, 1987, A Censoring Technique in the Monte Carlo Simulation Method Applied to Probability Based Distribution Line Wood Pole Design , in Probabilistic Methods Applied to Electric Power Systems, 978-0-08-031874-5, Toronto, Canada.

[12] Khatiba. T, Mohameda. A, Mahmoudb. M and Sopianc. K, an Assessment of Diffuse Solar Energy Models in Terms of Estimation

Accuracy, a Department of Electrical, Electronic & System Engineering, Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia, Bangi 43600, Selangor, Malaysia. b Department of Electrical Engineering, An-Najah National University, Nablus, Palestine c Solar Energy Research Institute, Universiti Kebangsaan Malaysia, Bangi 43600, Selangor, Malaysia.

[13] Linstone. H. A, Portland, Tuforr. M, 2002, The Delphi Method Techniques and Applications, 564889885, Murray Turoff New Jersey Institute of Technology with a Foreword by Olaf Helmer University of Southern California.

[14] Latief. A, Raihana. H. K, Sabaha. P, S. S. Mahdi, 2017, Measurement of Sunshine Duration. In Experimental Agrometeorology, A Practical Manual, Springer, Cham. https//doi.org/10.1007/978-3-319-69185-5_6

[15] Martínez. J. A, Tena .L. F , Onrubia J. E. , Rubia J.D , (December 1984), Agricultural and Forest Meteorology-Volume 33, Issues 2–3, , Pages 109-128.

[16] Nicolas. M, Frédéric. G and Patrick. S, 2010, Ant colony optimization algorithms, Artificial Ants. Wiley-ISTE. ISBN 978-1-84821-194-0.

[17] Rasdi. R. L .M, Ivan Fanany. M, 2015, Simulated Annealing Algorithm for Deep Learning a Faculty of Computer Science, Universitas Indonesia, Depok 16424, Indonesia, Procedia Computer Science 137 – 144.

[18] Seifi. H, Sepasian. M. S, 2011, Electric Power System Planning: Issues, Algorithms and Solutions, Vol-1, Berlin Heidelberg.

[19] Serfozo. R, 2009, Basics of Applied Stochastic Processes, Probability and its Applications. Markov Chains chapter 1, ISBN: 978-3-540-89331-8, Berlin Heidelberg.

[20] Stefu. N, Paulescu, M, 2016, Ångström–Prescott equation: Physical basis, empirical models and sensitivity analysis, "Renewable and Sustainable Energy Reviews", Vol. 62(C), pages 495-506.

[21] Srivastava. R. C, Pandey. H, Article ID 403742, 2013, Estimating Angstrom-Prescott Coefficients for India and Developing a Correlation between Sunshine Hours and Global Solar Radiation for India,Vol.2013, https://doi.org/10.1155/2013/403742, India.

[22] Talukder. S , 2011, Mathematical Modelling and Applications of Particle Swarm Optimization ,Master's Thesis Mathematical Modelling and Simulation Thesis no: 2010:8, Submitted to the School of Engineering at Blekinge Institute of Technology In partial fulfillment of the requirements for the degree of Master of Science .

[23] UNIDO, (2005), Technology Foresight Manual Organization and Methods Vol. 1, Vienna.

[24] UNIDO, 2005, Foresight Methodologies, Training Module 2, Vienna.

[25] Wang. D, Tan. D, Liu. L, 2017, Particle swarm optimization algorithm, Soft Compute DOI 10.1007/s00500-016-2474-6, The study was funded by National Natural Sciences Funds of China.

[26] Yazdanpanah. M. A, (2014), Modeling and sizing Optimization of hybrid photovoltaic/wind power generation system, Journal of Industrial Engineering International, Vol. 10, Article number: 49, Published

 05 March 2014.

[27] Definition at Markov_chain.org "Markov_Chain Wiki". Retrieved on
   25 May 2021.

[28] الطاقة الشمسية هي الآن ''أرخص كهرباء في التاريخ'' ، كما تؤكد وكالة الطاقة الدولية, 10.feb.2021.

 [29]https://cleantechnica.com/files/Solar-panel-price-per-watt-down-e1598761660994.png/8, 2020.

 [30] https://future.fandom.com/wiki/FuturologyTrend/,2021.

[31] https://www.talend.com/resources/what-is-data-processing/, 2021

[32] https://byjus.com/maths/Extrapolation/,2021.

[33] https://www.pveducation.org/pvcdrom/properties-of-sunlight/declination-angle ,2021

Appendix: -

solar radiation	Date
0.219	01/01/13 10:00
0.254	02/01/13 10:00
0.218	03/01/13 10:00
0.23	04/01/13 10:00
0.22	05/01/13 10:00
0.007	06/01/13 10:00
0.034	07/01/13 10:00
0.013	08/01/13 10:00
0.13	09/01/13 10:00
0.139	10/01/13 10:00
0.114	11/01/13 10:00
0.177	12/01/13 10:00
0.242	13/01/13 10:00
0.241	14/01/13 10:00
0.256	15/01/13 10:00
0.256	16/01/13 10:00
0.214	17/01/13 10:00
0.263	18/01/13 10:00
0.22	19/01/13 10:00
0.235	20/01/13 10:00
0.271	21/01/13 10:00
0.171	22/01/13 10:00
0.26	23/01/13 10:00
0.286	24/01/13 10:00
0.213	25/01/13 10:00
0.258	26/01/13 10:00
0.217	27/01/13 10:00
0.223	28/01/13 10:00
0.106	29/01/13 10:00
0.044	30/01/13 10:00
0.029	31/01/13 10:00
0.084	01/02/13 10:00
0.287	02/02/13 10:00
0.304	03/02/13 10:00
0.313	04/02/13 10:00
0.17	05/02/13 10:00
0.153	06/02/13 10:00
0.271	07/02/13 10:00
0.281	08/02/13 10:00
0.29	09/02/13 10:00
0.275	10/02/13 10:00
0.285	11/02/13 10:00
0.127	12/02/13 10:00
0.335	13/02/13 10:00

	0.144	14/02/13 10:00
	0.24	15/02/13 10:00
	0.131	16/02/13 10:00
	0.336	17/02/13 10:00
	0.351	18/02/13 10:00
	0.344	19/02/13 10:00
	0.352	20/02/13 10:00
	0.346	21/02/13 10:00
	0.319	22/02/13 10:00
	0.235	23/02/13 10:00
	0.248	24/02/13 10:00
	0.273	25/02/13 10:00
	0.386	26/02/13 10:00
	0.379	27/02/13 10:00
	0.368	28/02/13 10:00
	0.426	01/03/13 10:00
	0.394	02/03/13 10:00
	0.305	03/03/13 10:00
	0.291	04/03/13 10:00
	0.368	05/03/13 10:00
	0.425	06/03/13 10:00
	0.411	07/03/13 10:00
	0.404	08/03/13 10:00
	0.381	09/03/13 10:00
	0.375	10/03/13 10:00
	0.403	11/03/13 10:00
	0.419	12/03/13 10:00
	0.42	13/03/13 10:00
	0.437	14/03/13 10:00
	0.427	15/03/13 10:00
	0.286	16/03/13 10:00
	0.214	17/03/13 10:00
	0.336	18/03/13 10:00
	0.331	19/03/13 10:00
	0.461	20/03/13 10:00
	0.49	21/03/13 10:00
	0.497	22/03/13 10:00
	0.207	23/03/13 10:00
	0.549	24/03/13 10:00
	0.51	25/03/13 10:00
	0.429	26/03/13 10:00
	0.415	27/03/13 10:00
	0.345	28/03/13 10:00
	0.515	29/03/13 10:00
	0.504	30/03/13 10:00
	0.456	31/03/13 10:00
	0.425	01/04/13 10:00

113

0.422	02/04/13 10:00
0.54	03/04/13 10:00
0.354	04/04/13 10:00
0.363	05/04/13 10:00
0.493	06/04/13 10:00
0.488	07/04/13 10:00
0.385	08/04/13 10:00
0.234	09/04/13 10:00
0.354	10/04/13 10:00
0.346	11/04/13 10:00
0.483	12/04/13 10:00
0.184	13/04/13 10:00
0.568	14/04/13 10:00
0.586	15/04/13 10:00
0.169	16/04/13 10:00
0.111	17/04/13 10:00
0.253	18/04/13 10:00
0.271	19/04/13 10:00
0.035	20/04/13 10:00
0.077	21/04/13 10:00
0.476	22/04/13 10:00
0.507	23/04/13 10:00
0.602	24/04/13 10:00
0.612	25/04/13 10:00
0.622	26/04/13 10:00
0.619	27/04/13 10:00
0.604	28/04/13 10:00
0.616	29/04/13 10:00
0.608	30/04/13 10:00
0.453	01/05/13 10:00
0.521	02/05/13 10:00
0.569	03/05/13 10:00
0.587	04/05/13 10:00
0.587	05/05/13 10:00
0.58	06/05/13 10:00
0.536	07/05/13 10:00
0.612	08/05/13 10:00
0.313	09/05/13 10:00
0.603	10/05/13 10:00
0.389	11/05/13 10:00
0.352	12/05/13 10:00
0.622	13/05/13 10:00
0.372	14/05/13 10:00
0.184	15/05/13 10:00
0.512	16/05/13 10:00
0.411	17/05/13 10:00
0.485	18/05/13 10:00

0.522	19/05/13 10:00
0.577	20/05/13 10:00
0.608	21/05/13 10:00
0.625	22/05/13 10:00
0.636	23/05/13 10:00
0.61	24/05/13 10:00
0.536	25/05/13 10:00
0.425	26/05/13 10:00
0.574	27/05/13 10:00
0.612	28/05/13 10:00
0.624	29/05/13 10:00
0.586	30/05/13 10:00
0.603	31/05/13 10:00
0.602	01/06/13 10:00
0.601	02/06/13 10:00
0.572	03/06/13 10:00
0.611	04/06/13 10:00
0.606	05/06/13 10:00
0.623	06/06/13 10:00
0.215	07/06/13 10:00
0.484	08/06/13 10:00
0.447	09/06/13 10:00
0.471	10/06/13 10:00
0.603	11/06/13 10:00
0.618	12/06/13 10:00
0.484	13/06/13 10:00
0.509	14/06/13 10:00
0.453	15/06/13 10:00
0.542	16/06/13 10:00
0.529	17/06/13 10:00
0.535	18/06/13 10:00
0.6	19/06/13 10:00
0.598	20/06/13 10:00
0.599	21/06/13 10:00
0.429	22/06/13 10:00
0.572	23/06/13 10:00
0.6	24/06/13 10:00
0.55	25/06/13 10:00
0.601	26/06/13 10:00
0.609	27/06/13 10:00
0.623	28/06/13 10:00
0.37	29/06/13 10:00
0.454	30/06/13 10:00
0.448	01/07/13 10:00
0.492	02/07/13 10:00
0.535	03/07/13 10:00
0.606	04/07/13 10:00

115

0.633	05/07/13 10:00
0.564	06/07/13 10:00
0.585	07/07/13 10:00
0.587	08/07/13 10:00
0.59	09/07/13 10:00
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0.395	11/07/13 10:00
0.433	12/07/13 10:00
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0.465	14/07/13 10:00
0.563	15/07/13 10:00
0.545	16/07/13 10:00
0.442	17/07/13 10:00
0.493	18/07/13 10:00
0.411	19/07/13 10:00
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0.467	26/07/13 10:00
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0.567	29/07/13 10:00
0.497	30/07/13 10:00
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0.279	21/10/13 10:00
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0.349	15/11/13 10:00
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0.231	29/12/13 10:00
0.231	30/12/13 10:00
0.234	31/12/13 10:00