CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Solar radiation is intermittent in nature and the intensity of solar radiation falling on the surface of the earth directly and indirectly depends on several conditions. Climatic condition of India is tropical and throughout the year and it is possible to utilize the total amount of solar radiation received on the horizontal surface to derive useful energy. Measurement of solar radiation is indispensable for the design and development of solar thermal devices in all the locations. However, it is difficult to install and erect solar radiation measuring devices in all the locations due to increased capital requirement cost and maintenance. This has led to the installment of solar radiation measuring devices in certain specific locations in India.

Correlation equations can be developed using measured solar radiation in specific locations in terms of measured climatic and other meteorological parameters. The equations with a reasonable certainty thus developed can be used to predict solar radiation with similar climatic conditions. Researchers all over the world have made sincere efforts to correlate solar radiation and various climatic and meteorological parameters to derive correlation equations for predicting of solar radiation in the locations where measured solar radiation data is not available. Literature about the equations developed by the researchers and their inferences could serve as a powerful tool for the upcoming researchers in the field of solar radiation analysis. Based on the above mentioned facts, a detailed literature survey has been carried out to overcome the inconveniences in the existing models developed.
2.2 REVIEW OF LITERATURE

Detailed sky conditions for a location are necessary for analysing intensity of solar radiation throughout the year. Clearness and cloudiness index studies conducted by various researchers have been reviewed and presented in the following.

Perez et al. (1990) attempted to find the limitations in using the clearness index for the estimation of global irradiance. It was revealed that the time series of global irradiance led to noticeable gains with an optimum use.

Ahmad et al. (1990) proposed two correlations namely diffuse radiation in terms of global and extraterrestrial radiation. They found that diffuse solar radiation shows a peak value during the monsoon months of July-August.

Badescu (1994) established the relationship of cloudshade to point cloudiness and verified by using the same meteorological data of Romania.

Dependence of daily averaged point cloudiness in a day on cloud cover amount from the past two days in the locations was studied by Viorel Badescu (1997)

The Characterization of sky conditions at Ilorin, Nigeria using clearness index and relative sunshine was done by Udo (2000). Their Results revealed the non-applicability of Liu and Jordan’s cumulative distribution curves in tropical locations.

Ali Rahoma (2001) measured cloudless direct, global and diffuse solar radiations to find the spectral composition of direct and global solar radiations. The spectral composition of global solar radiation was found be
composed of 43% UV band, 32.5% band range 250-630nm, 13.74% red band, 52.75% infrared band and 29.7% diffuse solar radiation.

Li & Lam (2001) studied the climatic parameters and their applications in classifying sky conditions.

Dorvlo and Ampratwum (2000) proposed harmonic models using mean monthly average daily values of global irradiation for seven stations in Oman. Their results revealed that the one or two harmonics have shown a better fit of the data for almost all the stations.

Foyo-Moreno et al. (2003) attempted to find the influence of clouds on UV-irradiance. It was revealed that the effect of cloud has the least input on UV wavelengths and also a minor influence on the cloud cover for intermediate cloudiness.

Zarzalejo et al. (2005) utilized fuzzy logic and neural networks for estimating hourly global radiation from satellite images. The results revealed the efficiency of artificial intelligence models.

Ayodela & Ogunjuyigbe (2015) used probability distribution of clearness index to determine global solar radiation. The Validation of the model was done by measuring global solar radiation for a period of eight years in Ibadan, Nigeria. It was found to be effective in predicting the monthly average global solar radiation.

Moreno et al. (2014) studied the effect of clearness index and relative optical air mass on erythermal UV irradiance. The results of the study revealed that the relationship between the two effects led to the highest agreement in the optical mass range of 1.0, 1.2 and a clearness index range at 0.8 and 1.0.
A localized spectral analysis based on wavelet was done by Wayte (2007) to predict the power fluctuations by direct solar energy systems and the result revealed that it can be applied by power system operators for network planning in distribution grids with a high density of embedded generation.

Zhang et al. (2011) highlighted the importance of cloudiness factor in predicting net carbon absorption in the Asia monsoon region under climate change. It was revealed that the pattern of cloudiness index in the five ecosystem was not suitable for their net carbon uptake.

Varo et al. (2006) found that the model based on probability density distribution of instantaneous clearness index depends on the optical air mass and geographic and climatic conditions.

de Miguel et al. (2011) studied the influence of atmospheric factors (ozone, aerosols, precipitate water and clouds) on the ratio between erythermal (UVER) and total shortwave (SW) solar radiation. The results of the study revealed that this ratio is independent of solar zenith angle in a cloudy scenario.

Ogunjobi & Kim (2004) analyzed ultraviolet radiation, broadband global radiation and diffuse radiation at a station in Kwangju, South Korea. It was been revealed that the varying amount of columnar zone showed a 1% decrease in ozone leading to 2% increase in ultraviolet solar irradiance at zenith angles of 30° and 50° respectively.

Serrano & Bosca (2013) established a new zenith angle independent clearness index and found that the index is useful to classify cloudless sky conditions, in those cases when only the UV band measurements are available.
A modified clear-sky index for photovoltaic was proposed by Engerer & Mills (2014) and they proposed that the index is useful to predicting power output of nearby PV systems with a similar orientation.

Salazar and Raichijk (2014) analyzed the cloudiness state of the sky by utilizing values of clearness index and clear sky index. They found that Iqbal’s criterion for the classifying cloud cover in high altitudes did not provide best results.

Chen et al. (2015) proposed support vector machines model for estimating of global solar radiation from air temperature. It was found that accuracy of the prediction depends on distance, temperature difference between the estimation and the source site and the altitude of source site.

A combined empirical and Bayesias neural network models was proposed by Yacef et al. (2014) to estimate daily global solar radiation. The results revealed that the empirical model based on maximum and minimum air temperature better accuracy when compared to the Bayesian neural network model.

Shamim et al. (2015) used numerical weather prediction model to find the cloud cover index influencing the incident solar radiation. It was found that it is important to estimate global solar radiation compared with previous approaches.

A linear model was derived by adjusting empirical coefficients with respect to local applicability for estimation of global solar radiation Javier Almorox et al. (2013). Their results revealed that solar radiation can be estimated only when the temperature data are available.
Dumas et al. (2015) discovered the linear relationship between global daily solar radiation and the product of sunshine hours with daily maximum temperature variation. The results showed a comparative accuracy with monthly averaged daily values.

A General model for estimating daily global solar radiation was proposed using air temperature and geographic parameters in Southwest China by Li et al. (2013). Results showed that the site-dependent geographical parameter model has a better fit.


Almorox et al. (2011) developed a new model to estimate global solar radiation including differences between maximum and minimum air temperature and saturation vapour pressure at maximum and minimum air temperature. The proposed model provided the best estimation of global solar radiation.

Rahimikhoob (2010) tested artificial neural network to estimate global solar radiation using maximum and minimum air temperature and extraterrestrial radiation. It was concluded that artificial neural network techniques provided better results when compared to Hagreaves and Samani equation.

The Variation of air surface temperature influencing global, regional and local climatic changes was studied to determine the effect of magnetic field solar cycle and sunspot cycle by Echer et al. (2012). It was revealed that the magnetic field of solar cycle has a bigger impact on the Earth’s climate than a 11 year sunspot cycle.
The influence of altitude, distance to sea and reference temperature was incorporated in the previous models for monthly average global solar radiation using air temperature and the same was validated by Prieto et al. (2009). Results revealed the acceptable results for the prediction of global solar radiation.

Liu et al. (2009) proposed a new model for estimating of global solar radiation from daily range of air temperature in the absence of the duration of sunshine. It was found that the accuracy of the model was affected mainly by a larger range of air temperature.

Marti & Gasque (2011) used an artificial neural network, based on temperature for estimating of solar radiation. The proposed model with exogenous inputs have provided better results with lower associated errors.

Meza & Varas (2000) evaluated the behavior of the model based on the differences between maximum and minimum temperatures and the model based on sunshine hours for estimating global solar radiation. It was found that the model can be used in any location of Chile with correctly adjustable parameters.

Paulescu et al. (2006) found the possibility of computing global solar radiation using air temperature. The results of this model were acceptable with minimum errors.

Ajayi et al. (2014) developed a multivariate model in terms of location latitude, daily relative sunshine, maximum daily temperature, daily average relative humidity and cosine of day number to estimate the daily global solar radiation for any location in Nigeria. The proposed model predicted the global solar irradiance over Nigeria with minimum errors.
Artificial neural network based on high-level remote sensing products to estimate global solar radiation was developed by Qin et al. (2011). Results revealed that artificial neural network based method estimated monthly-mean daily solar radiation at a spatial resolution of about 5km with a high level accuracy.

Pan et al. (2013) tested the Bristow-Campbell model for the prediction of global solar radiation for Tibetan Plateau. It was confirmed that Bristow-Campbell model predicted global solar radiation with a reasonable degree of accuracy.

Menges et al. (2006) found the applicability of 50 models for monthly average daily global radiation on a horizontal surface of Konya, Turkey. Ertekin and Yaldiz model showed the best results for the estimation of global solar radiation.

Yohanna et al. (2011) proposed an empirical model for global solar radiation in terms of hours of bright sunshine and cloudiness. The solar radiation predicted by the proposed model was not found to be significantly different from the measured solar radiation.

Mamlook et al. (2001) developed fuzzy set methodology to find the order of solar system with higher priority to be used in Jordan. It was confirmed that solar distillation was found to be the best in terms of research and development in Jordan.

Gomez & Casanovas (2003) adopted fuzzy logic procedure to develop a model for solar irradiance on arbitrarily oriented inclined surfaces. The proposed model showed similar results for solar irradiance by Perez or Gueymard model.
The performance of artificial neural network (ANN), adaptive network-fuzzy inference system (ANFIS) and multiple linear regression models for the estimation of global solar radiation was analyzed by Citakoglu (2015) in Turkey. Their results confirmed efficiency of ANN model in estimating solar radiation in Turkey.

A hybrid solar radiation forecasting method was based on game theoretic self-organizing map (GTSOM) developed by Ghayekhloo et al. (2015). It was concluded that the proposed clustering method has superior performance when compared to the other method.

Grey-box modeling approach was adopted to predict the outlet water temperature of thermosyphon solar water heating system based on fuzzy system by Kishor et al. (2010). Results showed an improved prediction performance for the three inputs fuzzy model.

Boata et al. (2012) developed a new fuzzy model to forecast daily global solar radiation at ground level and attempted to quantify by means of clearness index. The proposed model performance was tested for European stations and the accuracy was found to be adequate for routine practical purposes.

Paulescu et al. (2008) proposed two models namely, self-dependent fuzzy modeling and fuzzy logic model for atmospheric transmittances. The results revealed the flexibility and suitability of fuzzy model input-output map to a local metro-climatic conditions.

Bhardwaj et al. (2013) adopted generalized fuzzy model to estimate the solar radiation accurately. The results of the proposed model were found to be in good agreement with the actual measured solar radiation.
Olatomiwaet al.(2015) attempted to find the accuracy of a soft computing technique for predicting solar radiation based on monthly mean minimum and maximum temperature and sunshine duration. The results revealed the efficiency of the proposed model.

Kisi (2014) found the ability of fuzzy genetic method to model solar radiation in seven cities in Turkey. The results have confirmed the applicability of fuzzy genetic method to estimate solar radiation using latitude, longitude, altitude and month of the year.

Cloud classification scheme based on fuzzy rule was used to estimate the cloud cover from satellite imagery and a high accuracy was achieved by the proposed method, Ghosh et al. (2006).

First order Sugeno fuzzy inference system were used for modeling and controller design of two axis sun tracking system by Alata et al. (2005). Results have shown virtual reality.

Sen (1998) proposed fuzzy algorithm of solar radiation from sunshine duration. It was inferred that solar radiation can represent solar radiation and sunshine duration relation as a set of fuzzy rules.

Qazi et al. (2015) attempted to use artificial neural network techniques for designing solar systems and predicting solar radiations on the basis of prediction accuracy and inadequacies. It was inferred from the results that the prediction accuracy using artificial neural network was less than 20%.

Lygouras et al. (2007) implemented a variable structure fuzzy logic controller for a solar powered air conditioning system. It was found that fuzzy logic is a common, inexpensive method with a special ability for fuzzy control.
Mintz et al. (2005) investigated the ability of an automated fuzzy logic method for the prediction of surface ozone concentration. The proposed fuzzy model has given the trends in ozone concentration and the trends were found to be in good agreement with the measured data.

Gairaa et al. (2016) proposed a new combined model by incorporating the linear autoregressive moving average with the nonlinear artificial neural network model to estimate of daily solar radiation. The results of the study revealed the improvement of the combined model over the ARMA and ANN models used in isolation.

Benghanem et al. (2009) developed an artificial neural network to estimate global solar radiation. It was found that model using sunshine duration and air temperature provides good results with a correlation coefficient of 97.65%.

Chen et al. (2013) presented a solar radiation forecast technique based on fuzzy and neural networks. It was revealed that combined fuzzy and neural network technique provided good results of solar radiation under different sky and temperature conditions.

Yaici & Entchev (2016) found the applicability of adaptive neuro-fuzzy inference system for predicting the performance parameters of solar thermal energy systems. The predicted values are in good agreement with the experimental results.

Hawas (1984) plotted the fractional time distribution of clearness index for Indian region. Their analysis confirmed the validity of Liu and Jordan’s approach and their correlation results are in good agreement with the experimental results.
Klein (1978) proposed $\phi$-chart curves for the prediction of flat-plate collector utilizability and results have revealed the easy implementations for utilizability using a programmable hand calculator.

Monsen et al. (1982) evaluated the monthly average auxiliary energy requirement of a building with a collector-storage. An empirical correlation for the fraction of the load met by the wall was derived based on solar radiation statistic, utilizability. The results revealed a coverage larger range of the design parameters.

Oliveira (2007) found the long-term performance of solar thermal systems for two different temperature levels corresponding to minimum and maximum operating temperatures quantifying through solar fraction, which is a function of monthly utilizability.

Oliveti & Arcuri (1996) validated the utilizability method for evacuated heat pipe solar panels and revealed and a critical comparison of the calculated and measured energy levels.

Evans et al. (1982) made an attempt to calculate the monthly utilizability for solar thermal flat-plate collectors applicable to south facing tilted collectors operated with a fixed fluid inlet temperature. It was found that the collector performance depends on site-to-site solar radiation variability.

Difference between the usage of hourly and daily insolation data in the utilizability method was found by Gordan et al. (1981). The utilizability curves based on daily insolation showed a significant difference from the curve based on hourly data increasing with an increasing threshold.

Suehrcke & McCormick (1989) threw right in the non-linear behavior of many solar energy system using utilizability curves based both on
hourly as well as daily insolation data. They found that solar collectors did not respond for radiation fluctuation, but it depends on instantaneous radiation fluctuation caused by the clouds.

    Palomo (1990) described the monthly hourly and daily utilizability function for flat-plate collectors including incident modifier angle. The results were found be satisfactory from the technical point of view.

    Gordan & Zarmi (1983) made an attempt to calculate annual utilizability theoretically and validated the same against the results based on meteorological data. The theoretical correlation is applicable for locations which are not covered by existing models.

    Chandrasekaran & Kumar (1994) estimated the daily utilizability by a simple method derived from cumulative frequency curves. Their results revealed that the simplicity and accuracy of this method is better than Klein’s method.

    Hazal & Langevine (1994) derived a simple tool in the form of a utilisability curve for designing solar thermal system with flat-plate collectors. The Significance of the method is highlighted their study.

    Two simple models to estimate the utilizability function values for non-tracking collectors were proposed by Armenta-Deu & De Andres (1991). They also compared the results with the original model of Gordan and Zarmi and the proposed method served as a validation test.

    Fraidenraich & Vilela (2000) calculated the time average of physical quantities which are non-linearly dependent on collector solar radiation. The results of the study are in good agreement with the experimental results.
Peter Kulisic et al. (1992) estimated the monthly average utilizability function for a photovoltaic system using hourly global and diffuse solar radiation. The results have been compared with the results of Klein’s equation and the coefficients in the equation were modified for the considered location.

Karatasou et al. (2006) proposed a simple method to calculate hourly and daily flat plate collector utilizability. The results were better when compared to the existing hourly and daily utilizability calculations.

Posadillo & Lopez Luque (2009) proposed three diffuse hourly radiation models and a method for a comparison of the performance of the models. Results revealed the best results for Reindl et al. anisotropic model.

Elasfouri & Hawas (1987) established a simplified simulation model to predict the thermal performance of solar systems. The results of the model confirmed that the system parameters influenced the performance of the system.

Suehrcke & McCormick (1992) calculated the average-daily solar system performance using the product of clear sky solar performance and the average time fraction of clear sky. It was found that the result of the proposed method was more favourable when compared with the result predicted by f-chart method.

Solar energy is an abundant, never lasting and available on site and it is pollution free. It can be utilized for distillation of water since the beginning of recorded history. Attempts were made 450 years ago to develop different types of solar stills even when drinking water was abundantly available.
Mahdi et al. (2011) designed and constructed a tilted-wick type solar still. The effect of water flow rate and salinity on the performance of the proposed still were measured. It was inferred that in clear days during summer, the daily efficiency was found to be 53%. Further, the efficiency was found to decrease with an increase in the salinity of input saline water.

Mahdi & Smith (1994) combined a V-trough solar concentrator with an inclined flat-plate wick-type solar still and analyze the results. It was found that the still with V-trough concentrator provided a fractional increase in efficiency and productivity on clear sunny days during winter than during summer.

Janarthanan et al. (2006) studied the performance of floating cum tilted-wick type solar still with the effect of water flowing over the glass cover. It was observed that the glass cover temperature decreased significantly and an optimum flow rate of water over the glass was found to be 1.5 m/s.

Karaghouli (1995) investigated the performance of wick-basin type solar still by connecting the hot waste brine water from the wick type solar still to the conventional basin-type solar still. The study has revealed that the wick-basin solar still showed better performance when compared to other types of solar still.

A basin type double slope solar still made of mild steel plate was tested with light cotton cloth, sponge sheet, coir mate and waste cotton pieces in the basin by Kalidasa Murugavel & Srithar (2011). The still was also tested with a rectangular fin covered with different wicks. It was found that the still with rectangular aluminium fin covered with cotton cloth has a significant impact on the performance of the still.

A theoretical analysis of tilted-wick solar still with inclined flat plate external reflector on a winter solstice day at 30°N latitude was done by
Tanaka & Nakatake (2009), who found that the amount of distillate output was 15% or 27% greater than a vertical reflector.

Tanaka (2011) presented a theoretical analysis of a tilted wick solar still with a flat plate bottom reflector whose length same as the still’s length. It was found that inferred that the distillate value was 13% greater when compared to the conventional tilted wick still when reflector’s inclination was 35°.

A new hybrid desalination unit consisting of evacuated solar water heater, jutegeo textile and solar still was designed and tested by Omara et al. (2013). It was concluded that water productivity was increased by 114% over conventional solar still for double layer square wick (DLSW) and average efficiency was found to be 71.5%.

Different designs of wick-type solar stills extensively reviewed by Manikandan et al. (2013), presented the advantages and disadvantages of wick type solar stills proposed by various researchers.

Yeh & Chen (1986) presented the effects of climatic, design and operational parameters on the performance of wick-type solar stills and derived a correlation equation for productivity by incorporating the above mentioned parameters.

A conventional solar still was provided with a blackened jute wick floating with a polystyrene sheet ½ cm above the water level (Al-Karaghouli & Minasian 1995). Their results have confirmed that the floating wick solar still provides a higher productivity when compared to the common tilted-wick type and basin-type solar stills.

Kabeel (2009) designed a solar still with concave wick evaporating surface and pyramid shaped condensing surface and tested. The results showed
that an average distillate productivity of 4.1 l/m², a maximum instantaneous efficiency of 45% and an average daily efficiency of 30% was obtained.

Velmurugan et al. (2008) augmented the evaporation of still basin water and fins integrated at the basin of the still. It was found that the productivity increased by 29.6%, 15.3% and 45.5% when wicks, sponges and fins were used.

The design, analysis and the performance of multiple wick solar still were done by Sodha et al. (1981). They discovered that the overall efficiency was 34% and the cost of the still was less than half the cost of a basin type still of same area.

A theoretical analysis of one step azimuth tracking tilted-wick solar still with a vertical flat plate reflector was done by Tanaka & Nakatake (2009). It was revealed that the average distillate yield was 41% when still was set with proper tilt angle and flat plate reflector.

An ordinary basin type solar still integrated with fins at the basin plate was constructed and tested for producing potable water from industrial effluents by Velmurugan et al. (2008). They recorded that the sponges, pebbles, black rubber and sand used in the fin type single basin solar still enhanced the distillate yield significantly.

Kabeel et al. (2012) investigated the performance of stepped solar still theoretically and experimentally and their theoretical results were in good agreement with the experimental observations of stepped still provided higher productivity than the conventional solar still.

A characteristic equation for a double slope passive solar still (DSPSS) based on experimental observations was developed by Dev et al. (2011).
It was revealed that the non-linear characteristic curves were more accurate for analyzing the performance of the proposed still.

Fluoride contaminated water was converted into drinkable water using a solar still by Sahoo et al. (2008). They observed that, when the capacity of water in the solar basin was raised from 10 to 20 L the fluorine reduced by 92-96% and the efficiency of the still increased by 11%.

An attempt was made to improve the efficiency of a solar still by introducing a medium to provide large evaporation surface and utilize the latent heat of condensation. They concluded that the introduction of jute cloth with regenerative effect i.e., water flowing over the glass cover increased the distillate yield by 20% and efficiency by 8%.

A transportable hemispherical solar still was constructed and tested by Ahmed et al. (2009) in Dhahran Climatic conditions. It was inferred that the efficiency of the still reached a maximum of 33% and decreased when the depth of saline water increased by 50%.

An experimental study of inverted absorber solar still (IASS) and single slope solar still was conducted by Dev et al. (2011) for the climatic condition of the city Muscat, Oman. It was found that the inverted absorber solar still provided daily yield of 6.302, 5.576 and 4.299 kg/m² day at water depths 0.01, 0.02 and 0.03m.

Cappelletti (2002) constructed and tested a still made of black plexiglass building materials, a sheet of transparent plexiglass for all boxes and a sheet of expanded polystyrene as insulating material. It was concluded that the elaborate design and increased cost did not improve the distillate yield of the distillate.
A detailed comparison of design, fabrication and water production of Tubular Solar Still with Vinyl Chloride material and polythene film as condensing surfaces was done by Ahsan et al. (2012). It was observed from the results that the still with polythene film has a noticeable cost reduction and better durability.

Ahsan et al. (2010) designed a tubular solar still with vinyl chloride as condensing cover surface. An empirical equation was also proposed to predict the hourly production rate by considering the humid air temperature and relative humidity fraction.

A simple single basin solar still was constructed to predict the optimum inclination of condensing glass cover in both summer and winter at 33.3°N latitude by Samee et al. (2007). It was concluded that the optimum inclination of glass cover was found to be equal to the latitude of the location.

Madholpa & Johnstone (2011) proposed a model to evaluate the distribution of solar radiation inside a basin-type solar still with plane reflector from the results. It was evident that the computed solar load on the surface of the saline water in the evaporation basin is lower than that of the load observed on a horizontal plane outside the energy system.

A tilted-wick solar still with an external flat plate reflector was theoretically analyzed to predict the optimum inclination of still and reflector by Tanaka (2009). It was evident from the results concluded that the still provides maximum amount of distillate yield by adjusting the inclination of the still and reflector for any season.

A double condensing multiple wick solar still has been designed by Tiwari et al. (1984) and tested. The results revealed that the excess vapor condensed in the second condensing cover and increased the distillate yield.
The performance of basin type solar still by using various different absorbing materials such as charcoal absorber and black-painted absorber was studied by Tiris et al. (1996) reported that the correlation developed has the best fit and the theoretical values were in good agreement with the experimental observations.

A transient mathematical model was proposed for a single slope single-basin solar still with and without PCM by El-Sebaii et al. (2009). It was observed that the still provided the distillate yield of 9.005 kg/m$^2$day with daily efficiency of 85.3% with the use of PCM and 4.998 kg/m$^2$day when the PCM was not used.

The thermal performance of a “V” type solar still with charcoal absorber and boosting mirror was studied by Selvakumar et al. (2008). It was evident from the results was observed that the efficiency of the still was found to be 24.7% (without charcoal), 30.05% (with charcoal), 11.29% (with boosting mirror) and 14.11% (with charcoal and boosting mirror).

A single basin double slope solar still was tested by Kalidasa Murugavel et al. (2008) with light cotton cloth, light jute cloth, sponge sheet and porous material of washed natural rock and quartzite rock as spread materials in the basin. It was revealed and shown that black light cotton cloth was found to be more effective in conventional solar still.

Different absorbing materials such as black rubber mat, black ink and black dye were used in the basin of a solar still and tested by Aihayaka (2004). The productivity of daily water were 38%, 48%, 60% for black rubber mat, black ink and black dye.

Abdallah et al. (2008) modified the conventional solar still using reflecting mirrors in the interior sides, a step-wise basin instead of a flat basin and a coupling sun tracking system. The thermal performance of the still was
found to increase by 30%, 180% and 380% for the usage of the mirrors, step-wise basin and sun tracking system.

Abdallah et al. (2009) used coated and uncoated metallic wiry sponges and black volcanic rocks in three solar stills. It was clear from the results that the uncoated wiry sponge provided the highest water output during daytime.

A weir-type solar still was designed by Sadineni et al. (2008) with double and single-pane glass covers and the production rate was analyzed. The productivity of weir-type still was found to be 20% higher than the conventional solar still.

A basin type solar still with improved condensation technique has been designed by Kumar & Bai (2008) and experimented. The minimum daily production was 1.4 l/m² day with an efficiency of 30%.

An experimental investigation has been carried out by Khalifa & Ibrahim (2010) with a basin type solar still with internal and external reflectors at tilt angles 0° (vertical), 10°, 20° and 30° for still cover angles of 20°, 30° and 40°. The result revealed that the most productive solar still in winter has a cover angle of 20° and internal and external reflector with an inclination of 20°.

A transient mathematical model was proposed by El-Sebaii et al. (2009) for an active single basin solar still both with and without a sensible storage material under the basin liner of the still. It was found that the annual average daily productivity with storage was found to be 23.8% higher than the still without storage.

A correlation was developed by Khalifa & Hamood (2009) for single basin solar still by incorporating the climatic, operational and design
parameters. It was inferred that the increase of insulation and interception of solar radiation increased with productivity.

A new radiation model was proposed by Felizadeh et al. (2010) for a single slope solar still by incorporating the effect of all the walls of the still and the amount of solar radiation on the water surface and each wall. Results showed that the effect of back and side walls should be considered for the accuracy of the thermal radiation analysis.

An active vibratory solar still was designed by using a vibrator installed in the middle of the system structure to generate forced vibration for the improvement of convective heat transfer by Eldalil (2010). The efficiency was found to be 60% with a distillate yield of 5.8 l/m²day.

Nijmeh et al. (2005) used various absorbing materials in a single basin solar still which include dissolved salts (potassium permanganate), violet dye and charcoal. The addition of potassium permanganate increased the efficiency of still 26%.

A new mass and heat transfer model was by Ahsan et al. (2010) by incorporating humid air properties inside the still. The water vapor density is found to be in good agreement with the experimental observations.

Khalifa & Hamood (2009) tested a solar still with insulation thickness of 0.03, 0.06, 0.10m to insert the storage of absorbed thermal energy. It was observed that the thickness of up to 0.06m insulation improved the productivity of the still.

2.3 RESEARCH GAPS

Literature pertaining to analysis of solar radiation by the researchers all over the world indicates the significance of correlation equation for estimating of solar radiation in terms of various meteorological parameters.
Also, an analysis of clearness and cloudiness index and equations for clearness index in terms of cloudiness index and vice-versa provided useful information regarding the climatic conditions of the locations considered. In both these cases, the correlation equations have been developed by researchers by considering the measured data of the locations and the same have been utilized for the prediction. This clearly reflects the prospects of error in the determining of clearness index and global solar radiation since the equations have not been derived from the data of the respective locations. Hence, it is imperative to derive correlation equation for global solar radiation and clearness index by using the long-term data of the location considered which would precisely determine the degree of solar radiation and clearness index.

Analyzing solar radiation and predicting correlation using the measured data for the locations have certain limitations, the most important being the measured data for all the locations are not available due to the non-availability of measuring devices. Review regarding the fuzzy logic modeling of various systems has thrown light on using fuzzy logic for estimating of solar radiation, as this method is simple and more viable when compared to the correlation equation, in terms of meteorological parameters. The inconvenience mentioned earlier can be overcome by introducing fuzzy system for predicting solar radiation with one of the most familiar dynamic variable, i.e., air temperature.

Estimation and prediction of solar radiation in various locations are useful in designing and analyzing the performance of the solar thermal systems. In addition to the short-term instantaneous performance, the long-term performance of any solar thermal systems can be determined using by different techniques. Many processes are necessary for the prediction. To simplify the difficulty, utilizability is a tool to predict long-term performance of solar thermal system. In this scenario, measured data based utilizability cannot be
determined in many locations since there is a lack of measuring device due to high capital and maintenance of the device involved.

Klein derived a correlation equation for utilizability fraction based on the measured US data. Klein’s method is very simple and powerful tool for determining utilizability. The applicability of Klein’s equation in Indian locations for utilizability can be confirmed as one of the easiest approach for utilizability in Indian locations. In this context, an attempt has been made to evaluate utilizability fraction in three important coastal areas using Klein’s correlation equation.

Research in the area of applying utilizability fraction for designing and optimizing solar thermal systems is meager and further efforts can be taken to determine the performance of solar thermal systems using utilizability. Solar distillation is one of the thermal applications of solar energy and the prediction of rate of production of distilled water can be found using utilizability method. Since Dunkle’s expression for determining production in solar distillation is quite complex, the utilizability can be used to predict the production of distilled water. Results of the study can be compared with the results obtained from Dunkle’s method and can be validated to employ the utilizability method for determining of production of distilled water.

Specific research gaps pertaining to the previous studies carried out by various researchers have highlighted the inconveniences of the models in measuring solar radiation, clearness index, utilizability function and application of utilizability function in the solar distillation. Therefore, it is necessary to develop methods to estimate the solar radiation on the basis of the more readily available meteorological data and utilizability function for predicting the productivity of solar distillation unit.