

## Chapter 2

### Review Analysis

#### 2.1 Introduction

In the previous chapter, the basic aspects related to energy scenario and importance of direct use of solar energy (especially by using concentrating solar collector) related to the present studies were observed. Current chapter includes the review of existing literature and their analysis pertaining to our research work. This is followed by the core literature related to the utilization of solar energy by the devices like parabolic dish and trough type solar collector and considering the experimental viewpoint for the development of solar energy across the various countries including India. The present chapter reviews the literature related to the parameters which influence the performance of concentrated solar power technology. At the end, research gaps are also identified to follow up in framing the objectives of the current study.

#### 2.2 Parabolic Dish Type Solar Collector System

Solar energy has importance in the current global discussions on energy and environment. Due to the high increase in the prices of fuel and energy, the search for an alternative cheaper source of energy is of great importance. As the world becomes more environmental conscious, there is a rising deforestation and finding renewable energy options to fossil fuels. The Earth receives 3.85 million Exa Joules (EJ) of solar energy each year (Johansson, Kelly, and Reddy 1993) [75]. Parabolic dish type solar collector system can be broadly utilized in two different ways : (1) cooking purposes and (2) power generation

### 2.2.1 Parabolic Dish Collector for Power Generation

Parabolic dish concentrator used for power generation offers the highest optical, thermal and exergetic efficiencies in comparison to all other types of concentrators which have been demonstrated and analyzed till today but they are not cost effective as it costs more per unit area of its construction. Generally, the study that was focused on parabolic dish collector for power generation are the thermal performance analysis of solar energy conversion [76]. Many researchers have studied the different components of parabolic dish concentrator system and the losses associated with it. Generally, the losses were studied in the spherical and cylindrical elements of the system. Optical losses were studied by the researchers Johnston et al. [77] which incurs in the reflecting surface of aperture of parabolic dish system. Aperture of solar dish system consists of reflecting surface made up of a polymer mirror film. It was concluded that the use of polymer mirror film is more economical in comparison to the use of curved glass mirror or polished aluminum mirror. They also suggested about how to minimize the complication that was arises during the manufacturing of multi-facet collectors. They use identical spherical reflectors as a sub-components to be mounted with a paraboloidal orientation to compare the manufacturing feasibility and optical performance. It was found that the placement of equilateral triangular pannel on the parabolic dish type surfaces constitute error of about 4% in comparison to others types of multi-facets.

Design and development of a cost effective solar steam generating system and its performance characteristics have been analyzed and investigated in [78]. The design of 10 kW solar Stirling engine was developed at the Sevilla Engineering School, Spain and the thermal analysis of it were presented by Garcia et al. [79]. Day by day, the sizes of the parabolic dishes are increasing with the introduction of new technologies and the advanced method of automated fabrication. Wua et al. [80] presented a design of 20 kW solar/Stirling engine to generate electricity through AMTEC project. In the last decade, research team of Australian National University developed 400  $m^2$  and 500  $m^2$  aperture of parabolic dish system for many years but majority of implemented systems requires large area of land and so expensive [81].

G.C. Bakos et al [82] proposed a power plant that uses Dish/Stirling technology to produce 10 MW of nominal power. They proposed a dish concentrator of multi mirror reflection. The primary mirror that was formed by the elastic film, uses the incoming solar radiation to focus on the secondary mirror and finally it was concentrated to the receiver where the Stirling engine was placed. They simulate the plant using TRNSYS program in order to investigate the performance under Greece climatic condition.

Yaqi et al. [83] studied the performance of solar operated Stirling heat engine and determine the optimum parameters using finite-time thermodynamics. They develop a mathematical model for the overall thermal performance of dish-Stirling engine by calculating the finite regeneration processes time and different losses.

On the whole it can be concluded that the parabolic dish type solar collector system for power generation is used widely using the different type of multi-facets like square, spherical and equilateral triangular etc. In our experimental work rectangular facets have been used to determine heat losses and performance index by putting cylindrical pot at the focus of parabolic dish type solar collector system. The literature on dish type solar collector system was done in the next section.

### 2.2.2 Parabolic Dish Collector for Cooking Purposes

The cooking sector has been considered a cardinal energy-consuming sector in the developing countries and there is a need to develop ways of exploiting these solar resources to its fullest so as to decimate the use of wood and other non-renewable resources (Mohit Bansal, Saini, and Khatod 2013; Erdem and Cuce 2013) [84, 85]. In a developing country like India energy consumed in cooking explains for 36% of total energy primary energy consumption and 90% of the country is still defenseless to the use starting from fuel woods and ending at liquefied petroleum gas (LPG) and electricity depending on their income, ipso facto, responsible for the deforestation (Pohekar, Kumar, and Ramachandran 2005; Muthusivagami, Velraj, and Sethumadhavan 2010; Nahar 2003; Gavisiddesha and Gorawar 2015; Pohekar and Ramachandran 2006) [86, 87]. Ipso facto, 70% of Indians live in rural areas where there are almost 300 sunny days a year, solar cookers have a

big potential in the country conducive to meet the energy demand especially in the domestic sector. In addition, utilization of solar cookers provides many advantages like no recurring costs, the high nutritional value of food, potential to reduce drudgery, and high durability (Erdem and Cuce 2013; Muthusivagami, Velraj, Sethumadhavan 2010; Nahar 2003) [85, 88, 89]. The Ministry of New and Renewable Energy (MNRE), Govt. of India has been pursuing a consummate program in the country on the development and awakening of renewable energy technologies most importantly cooking (Gavisiddesha and Gorawar 2015) [87]. Solar cookers are rather important applications in thermal solar energy conversion. The use of solar cooker for cooking purposes is spreading widely in most developing countries and in particular in villages and remote areas. The solar cooker must be high quality, affordable, user-friendly, light weight, stackable, and a family size. The history of solar cookers started early in the 18th century. Experiments on solar cookers were carried out by a German Physicist named Tschirnhausen (1651–1708). In 1767, De Saussure attempted to cook food via solar energy. He built a miniature greenhouse constructed from five square boxes of glass, bases removed, stacked on basis of decreasing size one inside the other atop a black wooden table for cooking fruit (Erdem and Cuce 2013; Saxena, Varun, and Srivastav 2011) [90, 85]. Similarly in 1830 an English astronomer Sir John Herschel also attempted to cook food in an insulated box cooker. In 1876, W. Adams developed an octagonal oven equipped with 8 mirrors and after one year Mouchot designed solar cookers. He also wrote the first book on solar energy and its industrial application. In 1930, India began to investigate solar energy as an option for avoiding deforestation. Funk (2000) [91] tested an old solar cooker and proposed international standards for testing solar cookers and reporting performance. Parabolic solar cookers concentrate sunlight to a single point. When this point is focused on the bottom of a pot, it can heat the pot quickly to very high temperatures which can often be comparable with the temperatures achieved in gas and charcoal grills. The concentrator is the major component from economic point of view. By reducing the weight of the structure, the reduction in the system cost becomes possible. A rationale with respect to economic design of a dish concentrator is to use the inherent strength of a paraboloidal shell in-

volving a deep dish wherein no frame would be required which, in turn, would reduce the weight and cost. The focal length should be small as in case of deep dish compared to a shallow dish (Kaneff 1983; Kaushika and Reddy 2000) [92, 78]. Parabolic cookers can reach extremely high temperatures with some of its varieties working without any cooking vessel. The parabolic solar cooker works on principle of the concentration of the rays. Parallel beam of ray of the sun is reflected on the parabolic mirror and the rays converge at a point, the hearth of the parabola. Determination of the exact receiver size and the arrangement to provide insulation at the receiver are of prime importance to avoid thermal losses (Gavisiddesha and Gorawar 2015) [87]. Basically there are two forms of losses associated with a solar cooker-optical and thermal losses. Optical losses are the ones taking place in the path of incident radiation before it strikes the collector while the thermal losses are those occurring due to convection and radiation. Heat losses from a Paraboloid concentrator basically depends on ambient temperature, pot water temperature, and the reflector orientation (Erdem and Cuce 2013; Subodh, Kandpal, and Mullick 1993) [85, 93]. The major problem being the hefty energy losses occurring constantly in the form of convection and radiation (main modes of heat loss from an open surface). The thermal losses associated with the dish type solar cooking devices have been evaluated by a fairly large number of authors over different climatic conditions.

Aidan (2014) [94] constructed a parabolic dish type solar cooking devices at Yola, Nigeria and evaluated it using international standard procedures and experimentally calculated optical efficiency, overall heat loss coefficient and cooking power to be 17.86%,  $8.896 \text{ WK}^{-1} \text{ m}^{-2}$  and 96.53 W, respectively. Habeebdullah, Khalifa, and Olwi (1995) [95] compared a bare receiver model and an oven model and found that fluid temperature did not cross  $120^{\circ}\text{C}$  even after 3 hours operation for bare receiver while for the oven under same condition the temperature reached  $233^{\circ}\text{C}$ . Better efficiency can be reached by the use of lighter weight oven (without sacrificing the insulation effect). Prakash, Kedare, and Nayak (2009) [96] carried out an experimental and 3-D numerical analysis (Fluent CFD) on steady-state convective losses and concluded that wind-induced convective losses are generally higher than the no-wind convective loss (varying between 22% and 75% for 1



Figure 2.1: Shows the cloudy under which the solar concentrating technology unable to focus the diffuse solar radiation

$m/s$  wind speed and between 30% and 140% for the 3  $m/s$  wind speed) at all receiver inclination angles, the only exception being the loss due to side-on wind at 0 receiver inclination angle.

The literature mentioned above is the application of solar energy to utilize solar radiation to convert it into thermal energy. But the problem arises when there is cloud in the sky or no sun condition. In the clean sky as shown in figure 2.2, the concentrated solar power performs well but in cloudy season as shown in figure 2.1, the extent of diffuse radiation increases in comparison to the direct solar radiation.

Under this condition, Phase change material (PCM) is used to store thermal energy of sun when there is sun and then transfer the stored thermal energy at the time of no sun condition. Although, there are various types of PCM like paraffin wax, fatty acids lauric acid etc. which are useful to store thermal energy at low temperature but  $Li_2CO_3/LiOH$ , called as high temperature PCM used to store energy at higher temperature. Moreover, another types of PCM called composite PCM have the enhance properties to store more energy in comparison to single PCM. Below are some literature on compos-



Figure 2.2: Shows the clean sky under which concentrated solar power performs well

ite PCM and the desirable properties it have been mentioned below as shown in figure 2.3 [69].

Vasishta D. Bhatt et al. [97] presents nine most suitable PCMs for thermal energy storage device. They studied rigorously about sixty PCMs and select most suitable PCMs based on the properties like thermal conductivity, heat of fusion, density and melting point. For the enhancement of storage capacity and different properties of phase change materials for the suitability of thermal energy storage device. Moussa Aadmi et al. [98] present the composite PCMs, epoxy resin paraffin wax with melting point  $27^{\circ}C$  as a new energy storage system. Ahmet Sari et al. [99] determines the thermal properties of blends of Polyvinyl alcohol(PVA)-stearic acid(SA) and Polyvinyl chloride(PVC)-stearic acid(SA) as form stable phase change material for thermal energy storage. In the blend, SA has a function of storing latent heat of fusion during its solid-liquid phase change where as the polymer(PVC or PVA) acts as a supporting material to prevent melted SA leakage because of its structural strength. A variety of polymer matrices are available with a large range of chemical and mechanical properties [100].

Latent heat storage material stores thermal energy while undergoing a phase

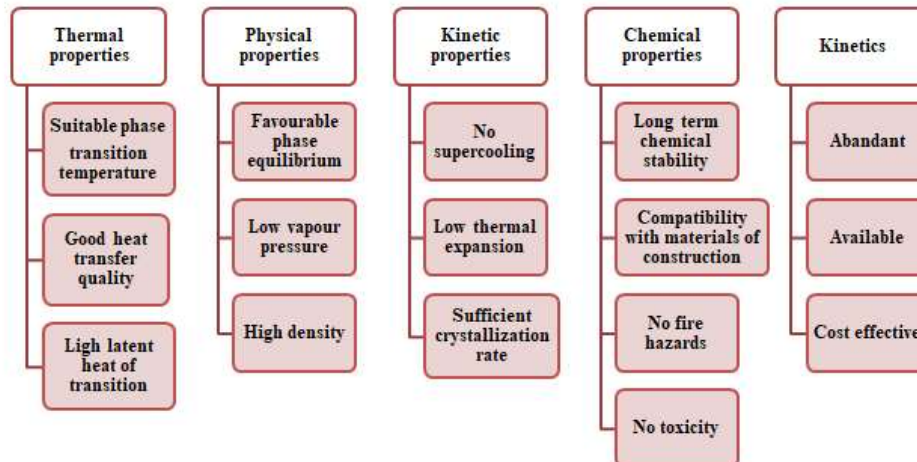


Figure 2.3: Desirable properties of phase change material for effective storage of solar thermal energy [70]

transformation. Developments of these storage systems include selection of material of desirable properties, material of containment and compatibility between these two. Initially latent heat storage material behaves like a conventional storage material but once the phase transition temperature reached, it acts as a latent heat storage material. Latent heat thermal energy storage system stores 5-14 times more heat than sensible heat thermal energy storage system [69]. After the selection of latent heat storage material, there must be a concept to develop heat exchanger which takes the stored heat away from phase change material and send it to the helical coil solar cavity receiver present at the focus of parabolic trough concentrator under consideration. Figure 2.4 shows the flow chart for the development of latent heat thermal energy storage unit under different stage. After going through the literature on storage system, it can be concluded that

### 2.3 Parabolic Trough type solar collector system

The rapid increase of energy demand projected the energy requirement of the world to be more than 60% of the current energy demand by the year 2030 [101]. Energy demand can be fulfill to some extent with the efficient use of concentrator. Although various types of concentrating collector mentioned above is used for power generation but parabolic trough power plants has the biggest share among all of them. PTCs provide over 90% of

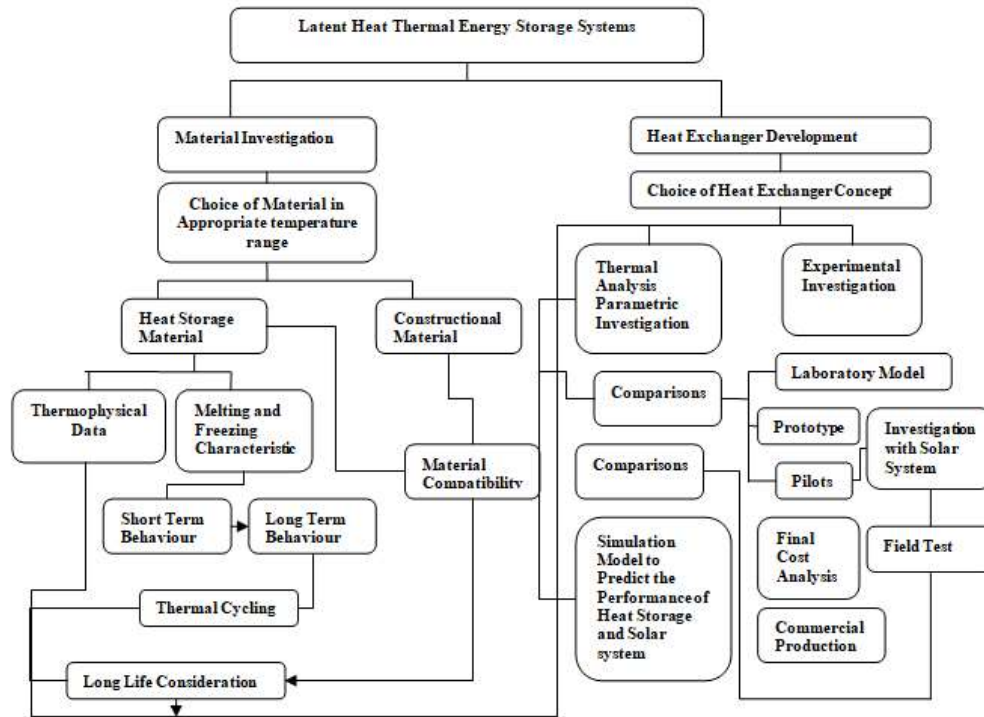


Figure 2.4: Flow chart for the development of latent heat thermal energy storage unit under different stage [70]

the total capacity that would be produced by four main concentrating solar power plant technology under operation or in construction in the year September 2010. At the same date, it was planned to install additional capacity in which the shares of PTCs are more than 50%. Fig. 2.5 shows the contribution of different concentrating technologies among the plants in, construction, operation, in the planning stage, and finally, the sum of shares of them for power generation [102].

John Ericsson in 1880 [103] constructed the first known parabolic trough concentrator for giving energy to engine whose working fluid is hot air. Adolf Remshardt and Germans Wilhelm Meier (1907) [104] was got the first patent in the field of parabolic trough concentrating technology to generate steam.

During the year between 1912 and 1913, The English F. Shuman and the American C.V. Boys installed the first solar thermal power plant in Meadi, Egypt. Using the Parabolic trough technology in the Gwal Gahari, the NES had established India's first solar power plant of 50 kilowatt capacity commissioned in 1989 and operated till 1990. In



Figure 2.5: Contribution of different solar concentrating technologies for power generation [100]

Mathania, a place in Rajasthan, India, 140MW of solar thermal power plant was proposed and approved by Rajasthan Government [105].

Ari Rabl (1975) [106] made differences and compared among the various types of solar concentrating collector for power generation as a function of general characteristics like acceptance angle, concentration ratio, size of aperture area, sensitivity to mirror errors, and the average number of reflections to develop PTC. Analysis of the relationship between, the acceptance angle, the concentration ratio and the operating temperature of the solar collector was done in simple intuitive terms to design collectors with maximum concentration.

E. Zarza et al. (2009) [107] suggested about the parabolic trough solar collectors to convert direct solar radiation into thermal energy and attain the maximum temperature up to  $400^{\circ}\text{C}$ . The working principle of these solar collector have been explained and also studied the basic governing equations as well as their thermal and optical behavior. They elaborate the methods of direct steam generation in the absorber tube of PTC (so-called

DSG process) and it was found that a PTC system for steam generation is a promising option for cost effective use of thermal energy produced by these collectors. At the same time, electricity production using PTCs has become the most outstanding industrial application.

O. García-Valladares (2009) [108] developed a performance model considering the optical, geometrical, thermal and fluid dynamic aspects of a single and double-pass solarparabolic trough concentrator. They also developed a simulated model and thermal and fluid dynamic behavior of PTC. The accuracy of the detailed simulated model is also demonstrated by them in their studies.

S.K. Tyagi et al.(2007) [109] They estimated the exergetic performance of concentrating collector. Parametric study was also done by them using hourly solar radiation to calculate the thermal efficiency. It was found to be the mass flow rate is an important parameter for PTC.

Scott A. Jones et al.(2001) [110] created a model of the 30 MW SEGS VI parabolic trough plant. It was developed using the TRNSYS simulation (solar thermal electric component model library). It shows the competency of model to perform detailed analysis. It is also useful to evaluate the proposed solar parabolic trough storage systems.

### 2.3.1 Solar Receiver Systems

The receiver is the backbone of any solar concentrating unit that is why many authors still working on technique to minimize losses. The receiver tube at the focus of concentrating collector is usually covered by the glass tube to block the infrared solar radiation coming from sun and reduce convective and conductive losses by creating vacuum at the annular space of receiver. Generally, solar thermal power plants use the space between the absorber tube and glass tube to reduce the loss of heat thereby increase in thermal efficiency. Vacuum creation between glass cover and receiver tube is fundamental to reduce heat loss in solar thermal application [111]. The vacuum and their stability at the annular space will greatly affect the heat loss in a receiver. Vacuum tube should be designed in such a way that there should not be any kind of vacuum loss i.e. working on vacuum

leakage is also important [112]. Li et al.(2012) [113] investigated the different reasons for the loss of vacuum in the annular of the solar receiver. They suggested the reason behind the heat losses and concluded that the accumulation and infiltration of hydrogen are the main factors for it. Therefore, removal of hydrogen from the annular space is essential. Although, it is impossible to remove 100% hydrogen from the annulus space but maximum amount can be reduced by the process of degassing and usage of getters in the receiver. Liu J et al.(2012) [113] developed a receiver with borosilicate glass to metal seal. They claimed that it reduces the vacuum loss and hence the reduction of loss from the receiver thereby increasing the efficiency of the PTC system. Zhang et al.(2012) [114] experimentally investigated the effects of wind, vacuum glass tube, radiation, and structural characteristics on the heat losses. They concluded that the thermal efficiencies of the receiver were found to be 0.791 and 0.472 in calm and windy days, respectively, at a test temperature of about  $100^{\circ}\text{C}$ . It was also found in some literature that selective coatings and annular pressure have the considerable impact on heat loss than the velocity of wind [115, 116, 117, 118]. Mohamad et al. [119] suggests that the heat losses depend on the surface area of the receiver and the temperature difference that arises between the surroundings and the working fluid. Glazing over metallic receiver also plays an important role. They revealed that the single glazing is more economical than that of double glazing for a shorter receiver but double glazing is advantageous for a longer receiver.

At the same time the it was suggested that the performance of receiver tube with single glass cover associated with it is better at low temperature of working fluid. Moreover, the receiver covered with the double glass tube has higher thermal efficiency at high temperature of working fluid [120]. Naeeni and Yaghoubi [121] studied heat losses from a receiver tube of the PTC at a 250 kW solar thermal power plant in Shiraz, Iran, considering the effect of the collector tilt angle, wind velocity and its allocation with respect to height from the ground. Arasu and Sornakumar [122] investigated the performance of a new PTC based water heater system with a hot water storage tank. The water temperature is increased from  $35^{\circ}\text{C}$  at 9:30 hr to  $73.84^{\circ}\text{C}$  at 16:00 hr at the average beam radiation during the collection period of  $699 \text{ W}/\text{m}^2$ . Performance model and heat

loss analysis of solar receiver have been presented in detail by the National laboratory of the U.S. Department of Energy [[123](#), [124](#)].

Different types of solar receiver for parabolic trough concentrator based on geometry and their performance has been shown in Table 2.1.

Table 2.1: Survey of solar receiver of PTCs based on geometry and their performances

Author's name	Technique used for heat transfer enhancement	Benefits to Parabolic trough receiver	Year	References
Reddy and Styandarayna	Internal porous fins	31.8% reduction in heat loss as compared to plain cylindrical receiver.	2008	[125]
Kumar and Reddy	Wall-attached porous discs inserts	Thermal efficiency of parabolic trough receiver was improved significantly	2009	[126]
Aldali et al.	Internal helical fins	Uniform temperature distribution on tube surface	2013	[127]
Munoz and Abanades	Internal helical fins	Thermal loss reduced by 7-18.6% and plant efficiency improved by 2%	2011	[128]
Cheng et al.	Unilateral longitudinal vortex generators	Lower wall temperature with the reduction of thermal loss by 2.23–13.62%.	2012	[129]
Delussu	Inlet blades with internal fins	Maximum temperature can be reduced by 8% on tube surface and temperature gradient along the length of receiver reduced by 35%.	2012	[130]
Mwesigye et al.	Twisted tape inserts	circumferential temperature difference reduced by 76%.	2013	[131]

Author's name	Technique used for heat transfer enhancement	Benefits to Parabolic trough receiver	Year	References
Wang et al.	Metal foam inserts	Optimum heat transfer enhancement ratio has been found out (1.4 to 3.2)	2013	[132]
Song et al.	Helical screw-tape inserts	heat loss were significantly decreased.	2014	[133]
Mwesigye et al.	Perforated semicircle plate inserts	Enhancement of thermal efficiency in the range of 3 to 8%	2014	[134]
Waghole et al.	Twisted tape inserts	There was tremendous improvement in Thermal-hydraulic efficiency was enhanced in the range of 135 to 205%.	2014	[135]
Demagh et al.	S-curved absorber tube	Uniform heat flux distribution on the receiver surface	2015	[136]
Wang et al.	Corrugated tube	Thermal strain was reduced and heat transfer coefficient increased by 13.1% and 8.4% respectively.	2016	[137]
Mwesigye et al.	Twisted tape inserts	Improvement in thermal efficiency by 5-10%.	2016	[138]

Author's name	Technique used for heat transfer enhancement	Benefits to Parabolic trough receiver	Year	References
Bellos et al.	Converging-diverging absorber tube	mean efficiency increased by 4.55%	2016	[139]
Jaramillo et al.	Twisted tape inserts	Thermal and exergy efficiency were improved.	2016	[140]
Xiaowei Zhu et al.	wavy-tape insert	The heat loss is found to be reduced by 17.5-33.1%	2017	[141]

## 2.4 Findings of the Review

Followings are the findings of the review:

- Concentrated Solar Power has become a more viable option for large-scale electricity generation with the recent improvements in materials, optics and structures.
- Earlier, the work has been done using straight tube receiver with single glazing.
- Most of the researcher have been worked over the geometry of solar receiver to enhance convective heat transfer coefficient and minimize losses.
- Reduction of heat loss and improvement in convective heat transfer coefficient are the major challenges in concentrating solar power technology.

## 2.5 Research Gap

Followings are the research gaps that needed to be work over it:

- Most of the solar receivers are horizontal tube or the tube with different inner surface geometry like internal fins, converging-diverging sinusoidal geometry, fin pin arrays, perforated plates, twisted tape inserts.

- But the design and fabrication of solar receiver with double glazing helical coil geometry for the improvement of thermal performance of parabolic trough collector is yet to be done.

## 2.6 Problem Statement

Followings are the problem statements:

- Receiver tube without glazing attributes to huge losses.
- Heat transfer fluid flow through straight tube has lower heat transfer coefficient.
- Analysis of effect of double glazing over different internal geometry of receiver surface is essential to know about the improvement of the convective heat transfer coefficient of double glazing helical coil tube receiver as compared to bare straight tube receiver.
- Effect of vacuum at glass to glass annulus and vacuum at receiver to glass annulus on the performance of receiver tube.
- More attention toward the design of solar receiver is required to minimize losses and maximize thermal efficiency.

## 2.7 Objective of the Study

Followings are the objectives of the present thesis:

- To develop the performance model the experimental setup for parabolic dish and trough type solar collector systems.
- Performance of PTC system using double glazing helical coil solar cavity receiver with vacuum at outer annulus and its comparison with bare straight tube receiver
- To study the yearlong experimental data with helical coil solar receiver system

## 2.8 Scope of the Study

Followings are the scope of the study

- Although the environmental and experimental data are collected from data monitoring station installed at roof top of CERD, Department of Mechanical Engineering, IIT(BHU), but the performance of PTC system can be predicted over the entire place of varanasi climatic zone of low variation of latitude angle.
- The input parameters such as : wind speed, wind direction, solar radiation intensity, relative humidity, air and ambient temperatures are affected by nearby buildings, trees etc. Hence, the system should be installed at the open place above the hight of trees or nearby buildings.
- Analysis of performance of PTC system has been done using collected data (EES software). But, the same data may be used to predict future performance newly designed receiver (simulation)
- Scope of the study is not restricted to India but it can be applicable to those places where the intensity of solar radiation will be greater than  $700 W/m^2$  for the duration of solar potential greater than 200 days.

## 2.9 Methodology of Study

The following methodology was used to carry out this research work.

- The place was selected on the roof top of CERD, Department of Mechanical Engineering, IIT (BHU), Varanasi, India, from where the reliable data can be collected.
- Collection of environmental as well as experimental data to identify the parameters that affect the performance of Parabolic dish and trough type Solar collector systems.
- Data for wind speed, wind direction, relative humidity, Solar radiation intensity, and Air temperature were collected for the whole year of 2017.

- Data were analyzed in the form of graphs and tables to understand the behavior of the system and problems which have been faced.
- Receiver temperature, inlet and outlet oil temperatures, system tilt angle, vacuum pressure etc. were measured with reference to time of the day and their corresponding plots have been plotted to analyze the experimental results.
- Performance model of helical coil Solar cavity receiver has been developed and validated with experimental results.
- Important conclusion were drawn from the above performance analysis.
- Making recommendations for the improvement of performance of PTC system.

The above methodology has also been depicted in the flow chart as shown in figure [2.6](#).

The present chapter has included the problem identification process in which the problem has been identified by gone through the various literature especially on line concentrating collector. The Problem is to reduce the heat loss by covering the receiver and creating the vacuum at outer annular space. Design and experimental analysis has been discussed in chapter-3.

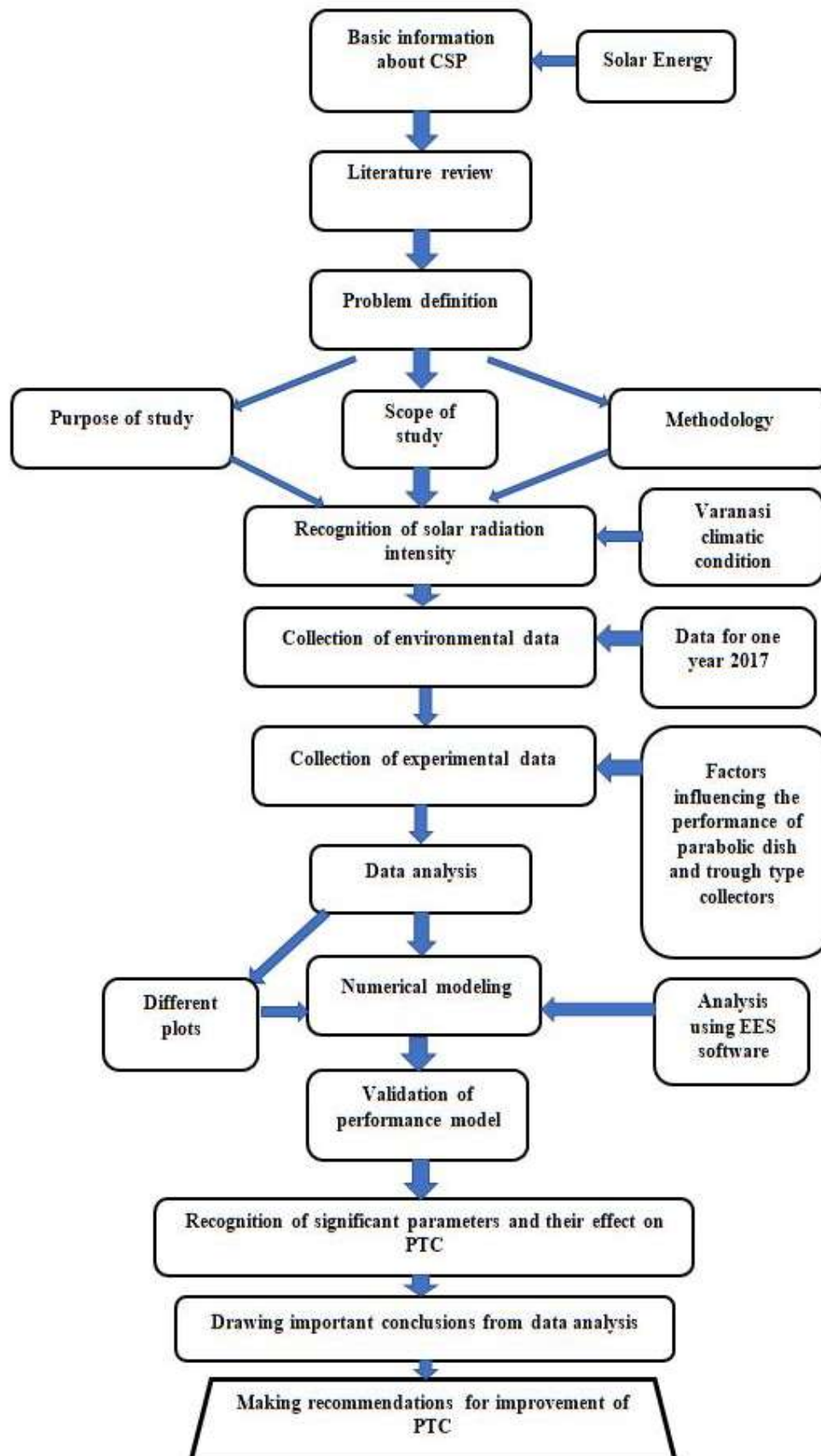


Figure 2.6: Flow chart of Methodology that was adopted for the present work