Design and Development of an Efficient Standalone Solar Parabolic Dish System for Building Electrification

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***Abstract*: Electrical power plays a vital role in social and economic development of any nation. Every activity of human life including domestic, agricultural, commercial and industrial requires continuous and reliable electrical power. Energy shortage, poor infrastructure and load shedding are the main causes of disturbances in this regard. To get rid of these disturbances, an alternate solution is to electrify the buildings with renewable energy based power plants. Besides the other precious renewable energy resources, concentrated solar power technology is an efficient and economical solution. Therefore this research work aims to design and develop an efficient stand alone small scale concentrated solar parabolic dish system for buildings. This proposed system will consist of a solar dish for concentrating the sun radiations on a fixed spot called focal point. The solar dish will be operated with dual axis solar tracking system to enhance the efficiency of photovoltaic panels fixed at its focal point. Dual axis solar tracking system will move the dish in horizontal and vertical directions to track the sun continuously throughout the day. The design parameters of the proposed dish system will be selected based on the continuous ratings within the building to be electrified.**

***Keywords*: Building Electrification, Solar Parabolic Dish System, etc.**

I. INTRODUCTION

Global energy demand and power consumption is increasing rapidly due to socio-economic development and population growth of the world. Various developing countries including Pakistan are facing severe challenges to provide clean and sustainable energy to their mass population [1]. Due to limited indigenous primary resources, poor infrastructure of the power system and unfocused attitude towards the solution of energy crises, country is facing an acute shortage of electrical power [2, 3]. The only solution to this critical scenario is to move toward the renewable energy resources available in the country like solar, wind, hydro, tidal and biomass [4]. Of these renewable energy resources, solar energy exhibits the highest potential globally. Pakistan is located at Sun Belt so blessed with abundant of solar energy [3]. Almost all parts of the country including sindh, Punjab and some south-western areas of Baluchistan are blessed with sufficient solar energy. In Pakistan about 50,000 MW of electrical power can be produced from solar energy [3]. There are different techniques to convert solar energy into electrical energy, like PV cells and CSP. Conventional PV panels are suffering from low efficiency, but their efficiency can be maximized if they are connected with parabolic dish as a standalone system of power generation [5].

A standalone solar parabolic dish system is believed to be the best alternate for any commercial or residential building electrification [1]. This system will help to energize and operate various important work machines and equipments which require continuous power supply. Therefore the aim of this research work is to design and develop an efficient solar parabolic dish system which will be capable to electrify the commercial and domestic buildings.

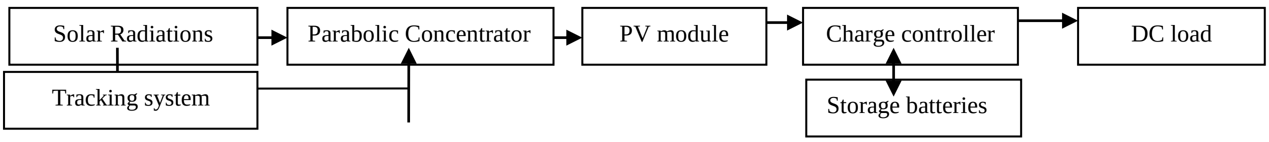

Fig. 1: Block diagram of standalone solar parabolic dish system

II. MATERIALS & METHODS

A. Standalone parabolic dish system

Standalone solar parabolic dish system is a CSP technology in which parabolic dish is used to focus the solar radiations on a PV module which is located at the focal point of the dish. Parabolic dish is integrated with a solar tracking system capable to move in the direction of sun throughout the day. This arrangement enhances the efficiency of PV module. This system comprises of five main parts; parabolic dish collector, receiving unit with solar PV module, tracking system, base with mechanical structure and battery backup. Solar radiations are captured by dish collector and directed toward the PV module. Due to photoelectric effect, DC potential difference of 12 V is generated at the PV module terminals. The dish collector strengthens the less dense radiations and confines them at its geometrical focal point. PV module is located at the focal point of the dish which receives the radiations and converts solar energy into electrical energy.

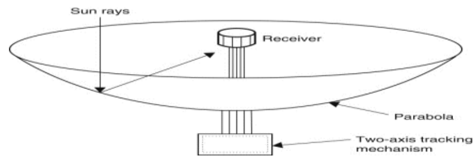

Fig. 2: Components of solar parabolic dish system [7].

To further enhance the efficiency of PV module, solar tracking mechanism is integrated with the system. This automatic tracking system will move the dish collector in the direction of sun continuously throughout the day [69].

B. Design and development of solar parabolic dish system

The design of a standalone parabolic dish system depends upon many factors like; reflecting material, diameter and aperture area of dish concentrator, Focal length, selection of PV module, area and diameter of receiver unit. The step by step design procedure of the parabolic dish system is illustrated in figure 2.

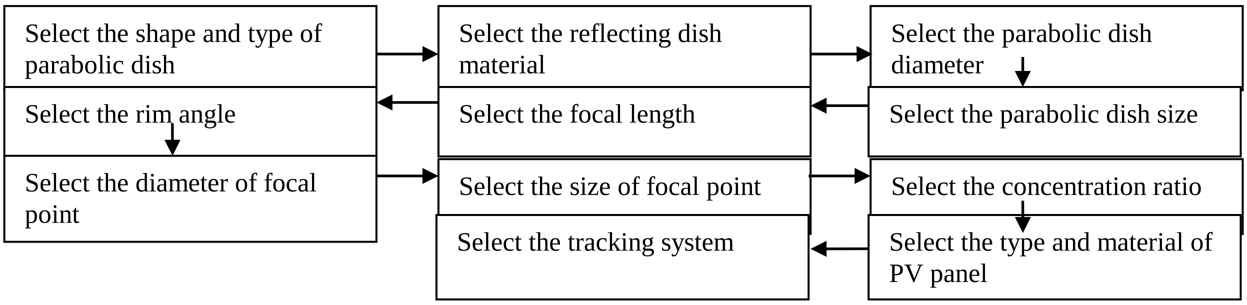

Fig. 3: Steps to design solar parabolic dish system

C. Shape and type of parabolic dish concentrator

Design of the parabolic dish depends upon its diameter, focal length, depth, and rim angle. In this research paper, Parabola calculator version 2 software is used to calculate the different parameters of the dish. Size of the parabolic dish depends upon its diameter. Selection of diameter is based on the solar radiations required. The general formula to calculate focal length (f), diameter (D) and depth (d) of the dish is given in equation 1.

$$F = D^2/16d \tag{1}$$

Aperture area is the total area of collector which receives solar energy. It is measured in square meters. Its size depends upon the amount of solar energy to be captured and directed toward receiver. The aperture area of concentrator is given by equation 2.

$$A\ conc = \Pi/4\ D^2conc \tag{2}$$

The reflecting layer plays a vital role for improving the efficiency of the system. Therefore selection of the reflecting is very important. In this research work pure aluminum polished mirror is selected for reflecting layer. This material has good reflectivity, low cost and is easily available in the markets. Table 4.2 shows different reflecting materials with their degree of reflection.

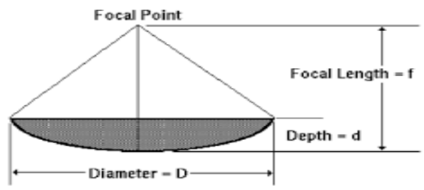

Fig. 4: Different design parameters of parabolic dish [6].

The material selected for the design of dish is galvanized steel. Since this material is not reflective, so its interior surface is polished with a reflecting material to increase its reflectivity.

Table 1: Reflecting Layers

Material	Reflectivity (%)	Cost in Rupees / ft^2
Radiant mirror film (3 MVM 200)	98	125
Mirror polished aluminum	85	150
Silver flux (3 M)	90	230
Acrylic mirror	85	500

D. *Focal length, Rim angle and Concentration ratio*

Focal length is the distance measured from lowest point on the surface of dish (vertex) to focal point. It depends upon diameter and depth of the dish collector. It can be calculated by equation 1. Rim angle is the angle measured between the lines passing from focal point to the edge of parabolic dish. Incoming solar radiations depend upon the value of this angle. It is considered the important design factor of the parabolic dish. Concentration ratio is the ratio of collector aperture area to receiver aperture area. The value of concentration ratio must be greater than 10. High value of concentration ratio will provide maximum heat energy at the receiver point. Formula for concentration ratio is given by equation 3.

$$C = Aconc/Arec \quad (3)$$

E. *Selection of the PV module and tracking system*

A solar module of 10 Watt with $0.043m^2$ size is selected and placed at the focal point of the parabolic dish. Solar tracking system is an automatic tracking system which rotates the parabolic dish and PV module in horizontal as well as vertical directions. It comprises of LDRs, an arduino circuit and dc motors. This system chassis the sun and moves accordingly, causing maximum solar radiations to be collected by parabolic dish.

III. RESULTS

The prototype of small scale standalone parabolic dish system is designed and operated experimentally. The complete system is located on the rooftop of the old administration block of Mehran university of Engineering and Technology Jamshoro. Several measurements of the output voltage, current and power are taken at different times. Results of the two systems, one with parabolic dish and other without parabolic dish are analyzed.

Table 2: Comparison of results taken on 21-2-2017

Time(H)	**PV module without parabolic dish**			**PV module with parabolic dish**		
	Ish(A)	Voc(V)	Po(W)	Ish(A)	Voc(V)	Po(W)
8:00	0.12	19.16	2.11	0.22	20.12	3.92
8:30	0.13	19.36	2.46	0.36	20.31	5.51
9:00	0.14	19.65	2.95	0.37	20.23	6.13
9:30	0.30	20.33	6.93	0.58	21.13	14.32
10:00	0.35	20.42	7.25	0.64	20.81	14.64
10:30	0.36	20.31	7.63	0.75	21.23	15.34
11:00	0.30	20.41	3.86	0.46	20.91	8.25
11:30	0.34	20.62	6.18	0.52	21.63	11.34
12:00	0.36	20.55	6.96	0.71	21.93	15.23
12:30	0.37	19.93	6.99	0.74	21.81	16.92
13:00	0.40	20.51	8.69	0.89	21.93	20.81
13:30	0.43	20.62	6.98	0.65	20.82	14.53
14:00	0.46	20.81	8.45	0.66	21.62	15.12
14:30	0.48	20.42	6.89	0.55	20.92	12.34
15:00	0.45	20.35	7.21	0.49	20.95	10.11
15:30	0.43	20.24	8.43	0.54	20.54	12.63
16:00	0.38	20.24	6.35	0.41	20.61	8.32
16:30	0.21	20.33	4.12	0.35	21.32	6.54
17:00	0.12	19.82	3.25	0.21	20.23	5.15
17:30	0.05	20.01	1.96	0.16	21.35	4.62
18:00	0.04	19.60	1.45	0.12	21.54	3.92

Results of the prototype model along with the PV module are measured experimentally using digital multimeter. The important key points regarding the performance analysis are discussed below:

- Average open circuit voltage of the system without parabolic dish is 20.17 V.
- Average open circuit voltage of the system with parabolic dish is 21.04 V.
- Average short circuit current of the system without parabolic dish is 0.29A.
- Average short circuit current of the system with parabolic dish is 0.49 A.
- Calculated average power of the system without parabolic dish is 5.57 W.
- Calculated average power of the system with parabolic dish is 10.74 W.
- Average output power difference of both the systems is 5.17W.

From the above analysis it is clear that the average output power of the standalone system is increased by 5.17 Watts when static PV module is connected with parabolic dish system.

IV. CONCLUSIONS

In this research work a static PV module is connected with a parabolic dish to design a small scale standalone system for power generation within a building to be electrified. The prototype model of the system is designed and operated experimentally on the rooftop of the old admin building of Mehran University of Engineering and Technology Jamshoro. The system is operated in two cases. In first case PV module is operated without parabolic dish and in second case a parabolic dish is connected with the PV module. Comparative analysis of both the systems is carried out in terms of their short circuit current, open circuit voltage and output average power. From the results it is concluded that if the static PV module is placed on the focal point of the parabolic dish, the average output power is increased by 5.17 Watts. Therefore it is concluded from this research work that a standalone parabolic dish can increase the efficiency and power of the static PV modules used for buildings electrifications.

V. RECOMMENDATIONS

The designed prototype is a small scale standalone parabolic dish system with 0.025KW rated power. However the size of the standalone system can be extended up to 1 to 10 KW, if size of the parabolic dish and solar PV module are increased. Furthermore the solar PV module can be replaced by a special heat engine known as striling engine which is capable to generate AC power directly.

VI. ACKNOWLEDGEMENTS

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