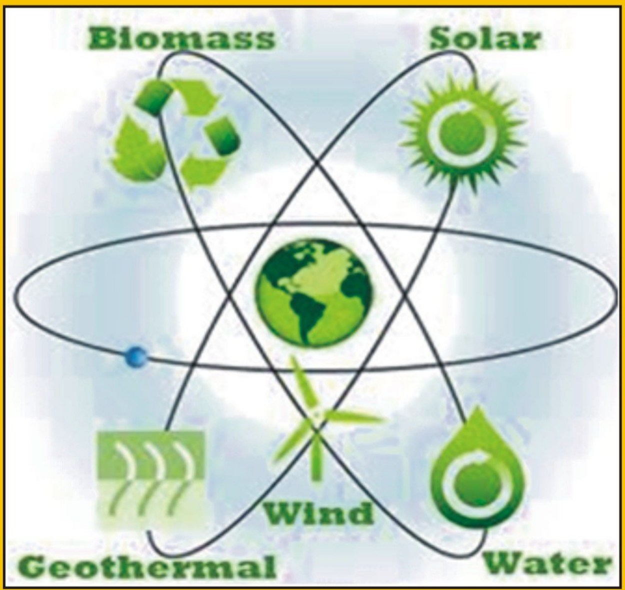
Compendium of Lectures



Renewable Energy for Sustainable Agriculture and Environmental Protection

March 8-10, 2021

Organised By:

उत्तमा वृत्तिस्तु कृषिकर्मैव

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Training Programme

On

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Organised by:

Department of Agri. Engineering, COA, SKRAU, Bikaner

and

Institute of Agri Business Management, SKRAU, Bikaner

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National Agricultural Higher Education Project (NAHEP) - ICAR

Solar dryer for drying fruits and vegetables of arid zone

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Introduction

Drying or dehydration of material means removal of moisture from the interior of the material to the surface and then to remove this moisture from the surface of the drying material. Drying is practiced to enhance the storage life, to minimize losses during storage and to reduce transportation costs of agricultural products. In India, 70% people depend on agricultural practices and of this most farmers are subsistence farmers and affording hi-tech facilities and equipment is a major problem. In many rural areas of India, the farmers grow fruit and vegetables. These perishable commodities have to be sold in the market immediately after harvesting. When the production is high, the farmers have to sell the material at very low price, there by incurring great loss. This loss can be minimized by dehydrating fruits and vegetables. The dried products can be stored for longer time in less volume. In off seasons the farmer can sell the dried products at higher price. The traditional methods for drying the agricultural produce is to dehydrate the material under direct sunshine. This method of drying is a slow process and usual problems like dust contamination, insect infestation and spoilage due to unexpected rain. These problems can be solved by using either oil-fired or gas fired or electrically operated dryers. However, in many rural locations in India, the electricity is either not available or too expensive for drying purpose. Thus in such areas the drying systems based on the electrical heating are inappropriate. Alternatively, fossil powered dryer can be used but it poses such financial barriers due to large initial and running cost that these are beyond the reach of small and marginal farmers. In the present energy crisis, it is desirable to apply a little solar technology for dehydration of fruits and vegetables, so that gas, oil and electricity can be saved. Fortunately India is blessed with abundant solar energy. During winter from November to February most of the Indian stations receive 4.0 to 6.3 kWhm^{-2} day^{-1} solar irradiance, while in summer season, this value ranges from 5.0 to 7.4 kWhm^{-2} day^{-1}. The arid and semi-arid parts of the country receive much more radiation as compared to the rest of the country with 6.0-7.4 kWhm^{-2} day^{-1} mean annual daily solar radiation having 8.9 average sunshine hours a day at Jodhpur, India, which can be used for dehydrating fruits and vegetables through solar dryer.

Solar Energy: A Promising Source for Drying Operation

Solar energy is one of the most promising renewable energy sources in the world compared to non-renewable sources for the purpose of drying of agriculture and industrial products. The concept of a dryer powered by solar energy is becoming increasingly feasible because of the gradual reduction in price of solar collectors coupled with the increasing concern about atmospheric pollution caused by conventional fossil fuels used for drying crops.

Solar drying in the context of this technical brief refers to methods of using sun`s energy for drying, but excludes upon air sun drying. The justification for solar driers is that they are more effective than sun drying, but have lower operating costs than mechanized driers. A number of designs have been proven technically, but while none yet is in widespread use, there is still optimism about their potential. Solar dryers are now being increasingly used since they are a better and more energy efficiency option. Solar dryer is an improved form of sun drying in which drying is accomplished in a closed structure under relatively controlled conditions utilizing the thermal energy of sun. Solar drying is to overcome the problems of traditional techniques and to give solutions to replace traditional techniques. If requirement of severe drying conditions is not there, then solar drying is used for most of the agricultural commodities. Solar dryers are optimistic options for overcoming the problems of crop preservation with the comparison of open air drying. Important factors to be considered in selection for a type of solar dryer for a particular product are:

(i) The amount of product to be dried

(ii) The recommended temperature for intended use

(iii) Amount of moisture to be removed for an expected storage life.

(iv) In addition to these; intensity of solar radiation, air temperature, relative humidity and moisture content of the product are the main factors that affect the drying process.

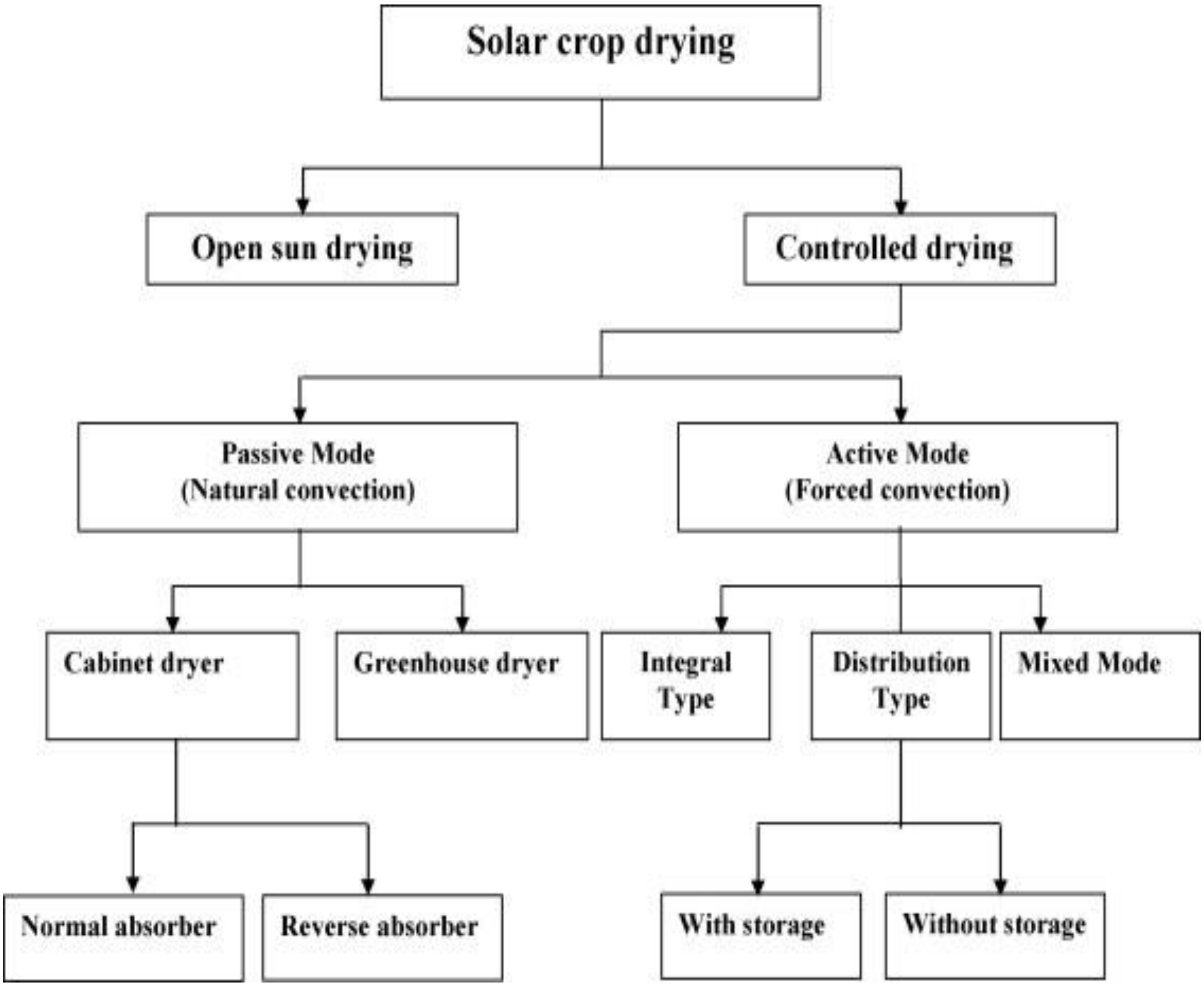
Solar dryer can be classified as:

(1) Passive

Passive solar dryer can further be classified as direct and indirect type. In direct type passive solar dryers the solar radiation is transmitted through the transparent cover and absorbed by blackened interior surface where, produce is kept for drying. Due to accumulation of energy the temperature inside the dryer increases as a result there is a continuous flow of air on the drying material. Such dryers are most suited for limited quantity of fruits and vegetables at domestic level. Indirect dryers are suitable for colour sensitive produce, as the produce is not exposed directly to the sun.

(2) Active

The active type dryers are suited for large scale application where blowers are provided for forced circulation of heated air.



Classification of solar dryers

1. Natural Convection or Direct Type Solar Dryers

Non-availability of adequate irrigation water and harsh climatic condition, generally prevailing in arid region, forces the farmer not to grow fruits and vegetables on large scale. As a result, the community in the region largely depend on tree/bush based non-conventional and locally available fruits and vegetables, viz., "Kumtia" (*Acacia senegal*), "Sangri" (*Prosopis cineraria*), "Gunda" (*Cordia myxa*), "Pilu" (*Salvadora oleoides*), "ker fruits" (*Capparis decidua*) etc. These products are either consumed as fresh with little primary processing and/or after drying. The vegetable "punchkuta" is prepared using these above tree/bush based dried vegetables and is one of the well-known preparations generally served in star hotels and on certain specific occasions in the region. In last one decade or so a drastic change has occurred with respect to increased consumption of conventional vegetables in the area. This has happened due to the import of these conventional vegetables from other states to the state of Rajasthan, particularly western part. Due to this change and local market demand the farmers of the region have started cultivation of vegetables with their limited irrigation water resources. However, the community in the region still have a choice to consume dry fruits and vegetables. The supply of these items from neighboring states as well as local production causes seasonal glut in the market. Fruit and vegetables, if dried, can be stored for a longer duration after drying and it enables farmers to accrue higher benefits by selling the dried material in off- season. Arid zones have low humidity and high irradiance and this makes the region most appropriate to use solar energy for drying fruit and vegetables. Solar dryer is a convenient device to dehydrate fruit, vegetables and industrial chemicals faster and efficiently with elimination of problems associated with open courtyard drying like dust contamination, insect infestation and spoilage due to rains. Among solar dryers like forced, natural, tilted and domestic type. CAZRI designed solar dryers, a low cost tilted type solar dryer, costing about Rs. 9000 per m^2, has been extensively tested for drying onion, okra, carrot, garlic, tomato, chillies, ber, date, spinach, coriander, salt coated amla etc. (Fig. 1).

Principle of inclined solar dryer

The solar dryer is based on the principle of flat plate solar collector and greenhouse effect. The solar radiation fall on the transparent glass sheet and enter the collector and get converted into long wave thermal radiations, which is not transparent to glass surface and thus these get trapped inside and increase the inside temperature to a great extent. However, the tilt of the dryer has to be set according to the seasonal variation of tilt angle, which is given as,

Declination angle = $23.45 \left[360 \left(\frac{284+n}{365}\right)\right]$------------------- (1)

Where n = number of day of the year, January 1, being the first day of the year.

Tilt angle = latitude ± declination angle.

The tilt remains equal to latitude (26.18° for Jodhpur) on March 21 and September 23. The average tilt angle for twelve months are given in Table 1

Table 1: Average tilt angle for different months of the year

S. No.	Day of month	Tilt angle
1.	January 15	48.45
2.	February 15	39.80
3.	March 16	28.60
4.	April 15	16.77
5.	May 15	7.39
6.	June 14	2.87
7.	July 14	4.66
8.	August 13	10.85
9.	September 12	21.96
10.	October 12	33.9
11.	November 11	44.09
12.	December 11	48.15

Performance of the natural convection solar dryer is very good during the summer but it is very poor during winter in northern parts of India and takes longer time for dehydration of fruits and vegetables because its absorbing surface is horizontal and so receive much less radiation compared to optimally inclined surface. Solar radiation received at Jodhpur on horizontal surfaces and optimally inclined surface is shown in Table 2. From Table 2, it is clear that solar radiation received on an inclined surface is 69.36 % more than a horizontal surface during the month of December and an inclined surface receives 43.8% and 22.76% more radiation than a horizontal surface during the winter season (October – March) and round the year, respectively. Therefore, optimally tilted solar dryer has been used for this study. The tilt of solar dryer is adjusted once in a fortnight as per elevation of the sun.

Table 2: Mean daily solar radiation (kWhm^{-2} day^{-1}) on horizontal and optimally inclined surfaces at Jodhpur

S. No.	Month	Solar radiation (kWhm^{-2} day^{-1})		
		Horizontal surface	Inclined surface	Increase over horizontal surface (%)
1.	January	4.61	7.25	57.23
2.	February	5.44	7.68	41.07
3.	March	6.39	7.27	13.74
4.	April	7.08	7.23	2.04
5.	May	7.39	7.39	0.00
6.	June	6.92	6.92	0.00
7.	July	5.86	5.86	0.00
8	August	5.42	5.46	0.87
9.	September	5.97	6.41	7.39
10.	October	5.69	7.24	27.07
11.	November	4.81	7.42	54.33
12.	December	4.33	7.34	69.36
	Mean	5.83	6.96	22.76

Figure 1: Inclined solar dryer installed at CAZRI solar yard

An optimally tilted type solar dryer can be used for dehydration of fruits and vegetables. The initial moisture content of tomato was reduced from 95% (wet basis) to about

5%, in spinach 93% to 5%, in carrot 71% to 12%, in ber 80% to 20% and in lasoda/gonda it was reduced from 85% to 10% within 2 days in solar dryer for tomato, spinach, carrot and gonda and 10 days for ber. The efficiency of the inclined solar dryer was 17.57%, respectively. The farmers can dehydrate vegetables when these are available in plenty and at low cost. Dehydrated vegetables can be sold in the off season when prices of vegetables are high and farmers can generate more income. The economic evaluation of the inclined solar dryer unit revealed that high value of IRR (84.4%) and low value of payback period (1.42 Years) make the unit is very cost efficient. One can save about 290 to 300kWh/m2 equivalent energy by the use of such dryers and farmers can accrue higher benefits from solar dried products. The use of the dryer would result on the reduction of the release of 1127 kg of CO2 savings/year. Solar dried vegetables will be more acceptable in the world market and farmers will get more income. The dryers are finding increasingly more acceptability due to export potential of dried products like garlic, onion, instant chatni etc. Based on this design a solar dryer of 400 kg capacity has been installed in village Kankani and of 1000kg capacity at village Keru village of Jodhpur district.

2. PV winnower -cum- solar dryer for winnowing and drying of food produces:

Winnowing and drying are two important post-harvest applications, which require attention. The villagers find difficulty in cleaning the threshed material if there is lull in natural winds, generally used for this purpose. Generally in rural areas, small farm holders thresh the material and then carry out the winnowing by pouring down the threshed material, which is kept on the locally available tray at a height with stretched hands. When the tray is shaken, the material falls down and if there is natural wind, it blows away the lighter particles and grain falls down. In the absence of natural winds, the farmers are handicapped and as electrical supply is intermittent, they have to wait for the wind. The PV winnower cum dryer have been used for winnowing threshed materials in the absence of erratic and unreliable natural winds and also for dehydrating fruit and vegetables more effectively and efficiently (Fig. 2). About 35 to 50 kg grain could be separated within 1 to 1.5 hours from threshed materials of pearl millet, mustard grain and cluster bean (Fig. 3). The same fan of winnower is used in a dryer to use the system for dehydrating fruit and vegetables under forced circulation of air. As a solar PV dryer 40-50 kg fruit and vegetables *viz.* water melon flakes, kachara (local cucumber) slices, grated carrot, mint, spinach, onion, mushroom, ber, coriander leaves, chilies etc. could be dehydrated in less than half of the time required in open sun drying while retaining its colour and aroma. Thus it become more useful for domestic lighting and for agricultural purposes such as winnowing and cleaning of grains and dehydrating fruit and vegetables enabling farmer to get more benefits from the same system.

Figure 2: PV winnower cum solar dryer

Figure 3: Winnowing of cluster bean (Guar)

3. Photovoltaic-thermal (PV/T) hybrid solar dryer

This solar dryer is unique as it is uses both thermal and solar photovoltaic simultaneously. The same unit is being used as solar collector as well as solar dryer. The solar photovoltaic fan regulate the temperature uniformly when solar radiation and ambient temperature are high, then the speed of fan is increased. The hybrid system has been designed and fabricated in such a way that it enabled the combined production of electrical energy and thermal energy from the photovoltaic panel and flat plate collector, respectively. The dryer consists of a collector unit, drying chamber, DC fan, PV panel and PCM chamber for thermal storage. The PCMs used were polyethylene glycol (PEG) 600 (melting temperature 17-23°C) during winter and polyethylene glycol (PEG) 1000 (melting temperature 33-40°C) during summer season revealed sufficient amount of heat storage in PCM materials during day time which further helps in drying of agricultural produces during night time. The PV module was provided at left side of solar collector to operate a DC fan for forced mode of operation. Dryer having a size 1250 mm × 850 mm was made by galvanised steel sheet (22 gauge), which consist of four drying trays. The clear window glass (4mm thick) is provided at the top of box. The area of collector designed for the dryer is 1.06 m2 with a DC fan of 10 watt, which was used for exhausting moisture with the help of a solar panel of 20 Wp. The dimension of two drying trays made of stainless steel angle frame and stainless steel wire mesh was (0.84 × 0.60 m) and that of two half trays (0.40 ×0.60 m). The drying material can be kept on four trays and placed on angle iron frame in the dryer through an open able door provided on the rear side of the dryer. Six plastic pipes are fixed in the back wall of the dryer just below the trays to introduce fresh air at the base. Actual installation of the photovoltaic thermal (PV/T) hybrid solar dryer is shown in Fig. 4.

Figure 4: PVT hybrid solar dryer installed at CAZRI solar yard

Different type of arid produces were dehydrated viz. ber, lasoda/gonda, tomato, spinach, carrot, ker and sangri in this dryer. The drying drying data of ber was fitted to four mathematical models viz. Henderson and Pabis, Newton, Logarithmic and Page models to predict the behaviour of ber drying. The logarithmic model was found to be the most suitable for describing the thin layer drying behavior of ber. The effective moisture diffusivity was 3.34×10^{-7} m^2/s and the efficiency of this dryer was found 16.7%. The developed hybrid PV/T drying system produces better quality products in shorter time by the efficient use of solar energy. The economic evaluation of the hybrid photovoltaic thermal (PV/T) solar dryer revealed that high value of IRR (54.5 per cent) and low value of payback period (2.26 Years) make the dryer unit is very cost efficient. The use of this hybrid PV/T dryer will prove to be a boon for remote location/rural area with less reliable conventional energy sources. It will go a long way in reducing post-harvest losses as well as CO_2 emission. The dried product of ber (*Zizyphus mauritiana*), Lasoda/Gonda, Anwala, Carrot, Mint leaves, Ker and Sangri (Unripe Pods of *Prosopis cineraria*) in solar dryer is presented in Fig. 5.

Ker fruit

Shredded Gonda/Lasoda fruit

Ber fruit

Sangri fruit

Figure 5: Solar dried fruits and vegetable

4. Solar tunnel dryer

In solar tunnel dryer agriculture and industrial products can be dried on large scale and small scale. It is a poly house framed structure covered with the UV-stabilized and poly carbonate sheets. Solar tunnel dryer is cheaper in operating cost and maintains moderate environmental conditions. Loading and un-loading of the products can be done in two ways:

- One man can enter to load and un-load the dryer through door
- Two handles are provided on the upper part of the dome shaped structure for loading and un-loading of the agriculture commodities.

Main principle of the solar tunnel dryer is to pass the short-wave of solar radiation through the poly carbonate sheet and UV-stabilized polythene sheet. The transmitted solar radiations are absorbed by the inside material and the short-wave radiation turns into a long-wave radiation inside the dryer because of this reason temperature rises inside the dryer. This effect is called as a greenhouse effect and this is the basic principle used in all solar thermal collectors. Solar tunnel dryer can be useful in most of the climatic conditions.

Advantages of solar tunnel dryer

- Both the air inlet and outlet of the solar dryer are insect-tight. Insects, such as wasps or fruit flies have no access and cannot contaminate the foods or chew up parts of them.
- Less dust can collect on the goods to be dried in a dusty climate.
- A brief episode of rain does not affect the drying results adversely
- Achievement of temperature is more inside the solar tunnel dryer compare to ambient temperature
- No running operating costs, environmentally friendly, energy self-sufficient.

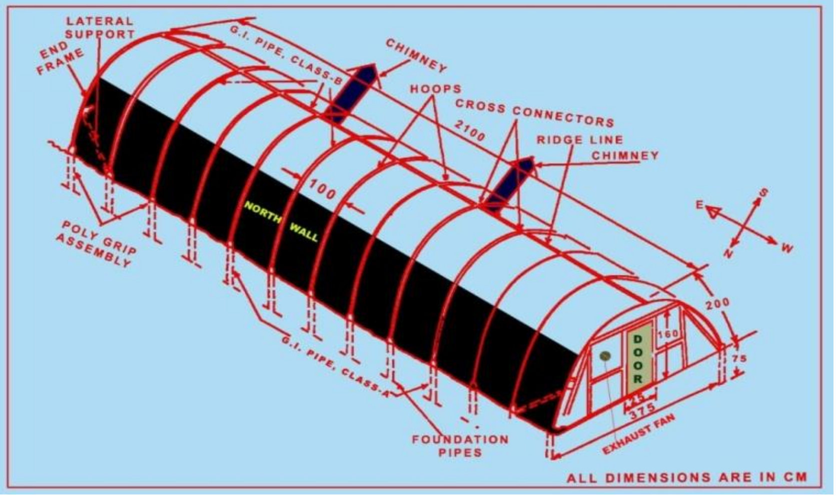


Figure 6: Schematic diagram of solar tunnel dryer

5. Greenhouse dryers

Greenhouse dryers could be classified either as direct solar dryers or sometimes as mixed-mode dryers. The greenhouse dryer is low cost, easy to fabricate, and simple in design. This can be used in any part of the world. Based on the mode of air circulation, the greenhouse dryers are classified into two types: (i) greenhouse dryer under passive mode (natural convection) and (ii) greenhouse dryer under active mode (forced convection). The typical design of greenhouse dryer is presented on Fig.6. The original greenhouse configuration was modified to allow for a black galvanized iron sheet absorber at the floor, air inlets along the whole length of both sides of the dryer, and air outlets along the upper part of the dryer. Both exits are equipped with fine plastic netting to protect the product against insects and dust.

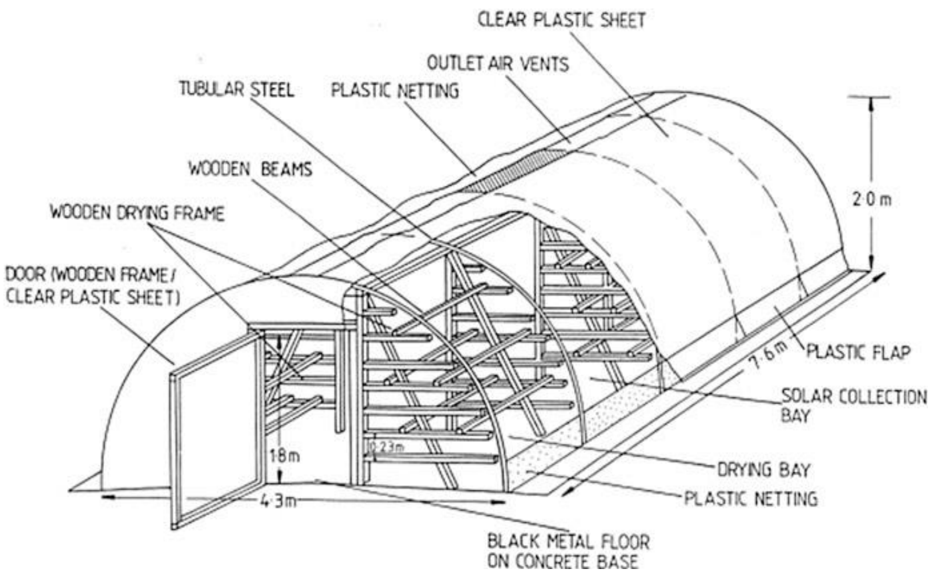


Figure 7: Natural circulation greenhouse dryer

Another type of forced convection greenhouse dryer with transparent polycarbonate cover is visible in Fig. 7. The dryer is approximately 5m wide and 10m long, and it is suitable for drying of different commodities such as fruits, vegetables, and spices. The dryer has trays stacked inside a wooden shed. Trays of size 2m × 2m are fixed in the wooden chamber to spread grapes. The air temperature inside the greenhouse dryer is approximately about 20°C higher than the ambient temperature depending on specific climatic conditions. Heated air passes through the trays placed in the wooden chamber. A blower is placed on the backside of the stack chamber to ensure a regular airflow through the trays. The size of the dryer shed is fixed at 2×3m which ensure easy loading. The frame is made from metal, and the dryer was covered by clear polyethylene material. The dryer consists of a plastic greenhouse cover containing a drying tunnel made with transparent plastic walls. The air circulation is ensured by an electric fan that moves the hot air from the greenhouse into the tunnel.

Figure 8: Solar greenhouse dryer

The main advantages of this dryer are continuous production, lower labor cost since the product handling was partly mechanized, a conventional heater which can be easily installed to keep a constant thermal efficiency, and the installation which can be used as a greenhouse for small production when it is not used as a dryer. Same authors investigated the evaporation rate in two types of forced convection greenhouse dryers, the single- and the double-chamber system.

Summary

There are no one simple criteria for selecting an appropriate solar dryer for a specific region in the world or a specific product to be dried. The classification of solar drying systems illustrates that the solar dryer designs can be grouped systematically according to drying air circulation to natural and forced convection dryers; according to operational modes to direct, indirect, and mixed-mode dryers; and by their heating sources. The most typical solar dryers for agriculture produce based on their construction designs were summarized and evaluated. The final selection of solar drying systems is generally based on the available insolation rate, kind of product that will be dried, production throughput, operational costs, as well as the experience of the fabricator. The use of solar dryers at remote locations/rural areas can go a long way in reducing post-harvest losses as well as carbon emission by supplementing/replacing conventional energy sources. The availability of clean and green energy source in rural areas would enable farmers to accrue higher monetary benefits through processing and agro-based industries to improve the livelihood of farmers and enhancing their standard of living.

Robust Control Techniques of Renewable Energy Sources in Microgrid

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Abstract

Power system is widely distributed and complex in nature. For the overall stability analysis of complete power system, the various aspects have to be examined properly. This article analysis the recent Indian grid disturbance occurred in July 2012. This article also investigates the effect of random measurement noise in grid connected microgrid. The primary control of grid-connected microgrid with four distribution generations (DG) units, is performed with and without measurement noise. The different power system stabilizer (PSS) structures are utilized in primary control action. The comparison of time-domain response having without any PSS, with conventional PSS (Delta PSS and Pa PSS), MB-PSS and robust Fuzzy Logic based PSS, is done. Using a typical test microgrid model, the performance of robust controller as a power system stability agent is accessed via time domain simulation of the test microgrid model on MATLAB/Simulink platform.

Index Terms-Microgrid, Fuzzy logic Control, power System Stabilizer, Multi Band Power System Stabilizer, and Noise.

Introduction

The modern power system is very complex, widely distributed inter-connected non-linear system. The interconnection of micro-grids, with the main or principle control grid is quite difficult task because of technical as well as economic reasons. Because of versatility, aggressive speculation costs and adaptable operation, non-renewable energy source era advancements have been the most widely recognized decision for supply of power in these remote grids. With the exhibited specialized and sparing practicality of greener era advancements in light of wind, sun oriented, hydrogen and hydro control, coordinating these advances has turned into a need in microgrids [1]. The details of Indian regional grids and corresponding evolution are shown in figure 1 and 2 respectively.