Solar photovoltaic-powered ventilation and cooling system of a greenhouse

Greenhouse technology is a major breakthrough in the field of agriculture as it gives higher productivity of crops and flowers and also promotes off-seasonal cultivation. This technology is important for a developing country like India, whose population is increasing by leaps and bounds thereby imposing a pressure on land available for cultivation. In order to promote off-seasonal cultivation inside a greenhouse, an artificial microclimate is required which may be maintained using a suitable heating or cooling system with humidity control depending upon the climate of the geographical area. In the plains of the Indian subcontinent the climate is hot for greater part of the year, except during the winter. Thus, for greenhouses located in the plains of India, the main objective is cooling and in some cases cooling along with dehumidification. Such greenhouses thus need electricity on a continuous basis to maintain the desired micro-climate inside. In India, considerable fraction of the rural population does not enjoy grid electricity and there are about 94,000 unelectrified villages in India[1]. Out of these, 25,000 villages are located in such remote areas that extension of existing electricity grid is not economically viable. So establishment of an independent greenhouse is a genuine need of the hour. Even for greenhouses that can be powered through grid-connected electricity, problems of low voltage and high power fluctuation are common and there are frequent power cuts due to load shedding or breakdown. Thus, for greenhouse installation in rural areas, the requirement of electricity on a continuous basis imposes significant restriction, leading to increased cost and reduced operational reliability.

For regions where plenty of solar radiation is available, as in the plains of the Indian subcontinent, use of solar energy to power a greenhouse is a viable option. The solar energy can be harnessed by mounting solar photovoltaic (SPV) modules on the roof or sides of the greenhouse. But as solar energy is not available at night or may be insufficient to generate the required electrical energy to operate greenhouse utilities round the year, some form of power back-up arrangement is necessary. The most common type of power back-up arrangement used at present is the battery.

In most cases, the solar energy in DC mode is used for various applications. However, the cost of DC appliances is more compared to the existing AC appliances. The solar power generated is of DC type, which is used directly to run the DC appliances, which are generally more expensive than AC appliances. However, if DC is converted into AC with the help of an inverter, the AC power can be conveniently used to operate the conventional available AC appliances without investing any extra cost[2].

Here a study of SPV system to operate the fans and cooling system of a fan-pad ventilated greenhouse has been presented. A solar panel of 600 W (open circuit voltage 17 V) was used to operate the system. The DC power of the solar panel was converted into AC power with the help of a 24 V/1250 VA inverter. A battery was used to provide back-up to the system in the absence of solar energy. With the AC output from this system, a load, of 304 W consisting of two exhaust fans and a cooling system pump was operated successfully.

A SPV panel consisting of six modules each of 100 W (20 V open circuit voltage) was used. Two modules were connected in series to give 24 V output. A string of three of these were connected in series to enhance the current output. With this system a total of 24 V, 15 A and 600 W power was available. A pulse width modulation (PWM)-type solar charge controller of 24 V and 40 A capacity was used to supply the controlled DC power of solar panels to the batteries and finally to the inverter. Two batteries of 12 V each of 150 Ah and 40 Ah were connected in series to provide 24 V DC

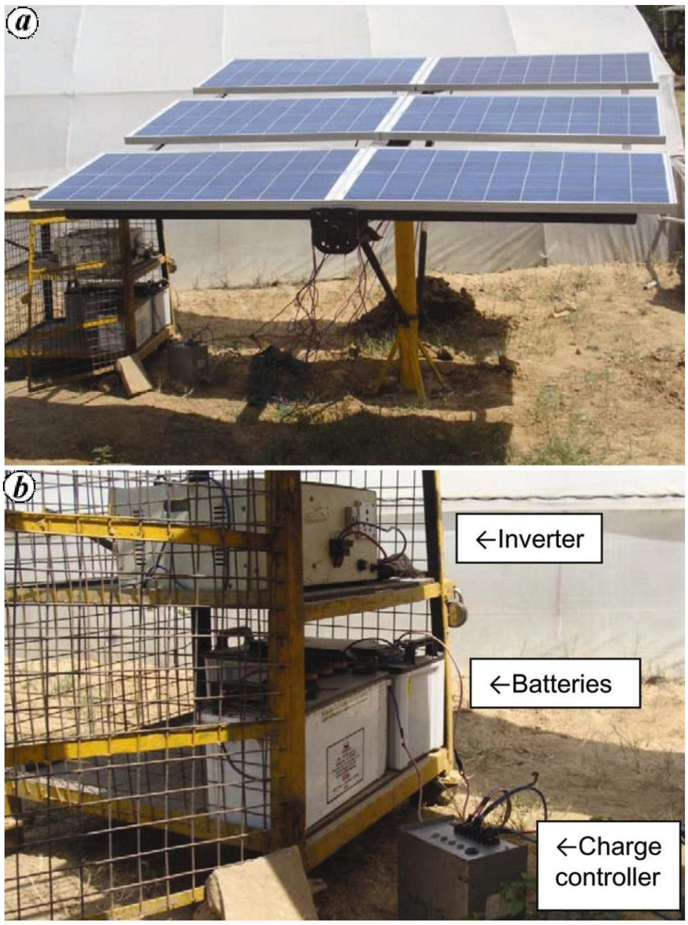

Figure 1. ***a***, Solar modules of 600 W power pack system. ***b***, View of inverter and batteries.

Figure 2. Solar photovoltaic-powered exhaust fans (***a***) and fan-pad cooling system (***b***) in the greenhouse.

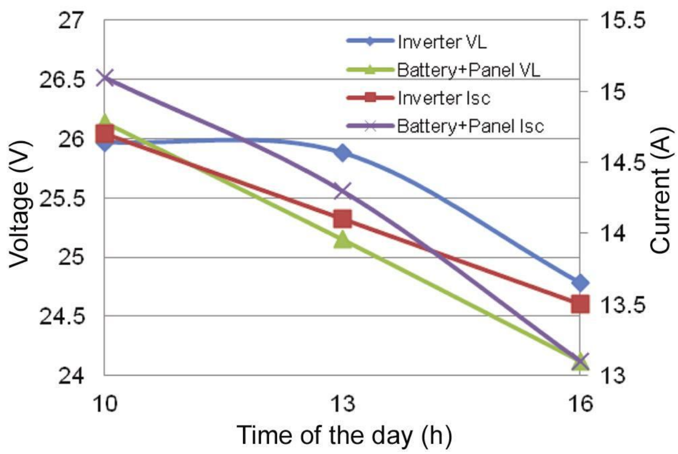

Figure 3. Variation of voltage and current at different times of the day.

output and 190 Ah. Batteries were used for storage of the DC power generated by the solar panel to meet day load requirements and to provide the back-up when the solar energy is not available. A 1250 VA inverter was used for conversion of solar panel and battery power into single-phase AC power for various appliances. The greenhouse used in the study is a 24 m^2 (6 m × 4 m) Quonset type greenhouse. It has two exhaust fans of 132 W each and a cooling pump of 40 W. Earlier, a cooling pump of 375 W was being used. However, it was replaced with a 40 W submersible-type pump to save power without compromising on the performance.

A solar panel of 600 W (open circuit voltage 17 V) was used to operate the system (Figure 1 *a*). The DC power of the solar panel was supplied to the battery (24 V) through a charge controller. From the battery this DC supply was given to the 24 V/1250 VA inverter to convert it into AC (Figure 1 *b*). The AC output from this system was used to operate the 304 W loads consisting of two exhaust fans and a cooling pump (Figure 2). The system was operated from 10 a.m. to 4 p.m. when the solar light was available on the solar panel. The voltage at load (V_L) was measured at the output point of the inverter and the solar panel and battery. The variation of voltage and short circuit current (I_{SC}) at different time of the day is shown in Figure 3. The figure shows that the V_L initially remained more or less constant on load for first 3 h of operation due to sufficient incoming solar radiations but it decreased slightly afterwards with time due to weak incoming solar radiations as the evening approached. However, the voltage did not decrease below rated battery voltage 24 V after 6 h of on-load operation. These results are in agreement with those reported earlier[3]. The appliances were operated successfully for the above-mentioned period. Since an exhaust fan requires more starting current, no problem was encountered while starting the fans. Using a battery of bigger size such as 300–360 Ah, back-up to the system may be provided during night when the solar energy is not available.

The potential of using a photovoltaic (PV) system to power greenhouses has been studied. The availability of solar radiation matched with the demand for electrical power (SPV). The performances of the PV subsystem, battery subsystem and greenhouse cooling system were satisfactory. The present study shows that PV power is technically a viable and adequate option for supplying electrical power to greenhouses in remote areas. In view of this, the solar energy can be utilized efficiently with the existing available equipment for successful operation of different domestic appliances in a pollution-free environment and at minimum operational cost. It is particularly useful for application in rural areas for meeting the power demand. Once the initial cost of installation is met, the electricity generated by solar panels is almost free of cost. In a stand-alone solar power system, one does not have to pay any utility bills. Another positive aspect of installing solar power systems is that the government offers rebates and incentives to cover the initial cost. The system can pave the way for sustainable cultivation in self-sustained greenhouses even in remote areas, where probability of getting conventional grid-connected electricity at a steady voltage round the year is very low.

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Petrographic and XRD studies on a new occurrence of molybdenite within late Archaean mafic enclaves near Hyderabad, eastern Dharwar craton, India

Molybdenum is a group 6 transition metal with an atomic number 42. It occurs in nature only in chemical combination with other elements. The average crustal abundance of molybdenum is 1.2 mg/kg (ref. 1). Molybdenum is extracted from two principal ore minerals molybdenite (MoS_2) and wulfenite ($PbMoO_4$); however, molybdenite is a more common ore mineral. Molybdenum is reported from all over the world, though only few countries like China, the United States, Chile and Canada are the main producers[2]. It is an important element in making many types of steel alloys and super-alloys. Due to its ability to survive extreme temperatures without significantly expanding or softening, it is useful in making armor, aircraft parts, electrical contacts, industrial motors and filaments[3]. Generally, rhenium (Re) which is widely used for making super-alloys and as a catalyst, is also found to be associated with molybdenum. Radioisotopes of rhenium ^{188}Re and ^{186}Re are used for treatment of liver and pancreatic cancers. Therefore, any new report of molybdenum, by inference molybdenite, from the Indian shield may be an important finding.

Occurrence of molybdenite in India is summarized in the GSI Dossier (Figure 1; Singanenjam *et al.*[4]). A report of molybdenite in granitic plutons from the Pirancheru area near Hyderabad is also documented[5]. Structurally molybdenites are generally associated with shear zones, fracture systems and fold hinges[4]. Most of these molybdenite occurrences are associated with Pan-African to late Proterozoic (500–800 Ma) granites. However, molybdenum occurrences during Neoarchaean to Palaeoproterozoic are also known; for example, Kolar Schist Belt, Andhra Pradesh[4] and Yegavkote near Chintamani, Karnataka[6]. It is important to mention that except one[5], all other[4] molybdenite occurrences are associated with other metal sulphides. The molybdenite occurrence in granite pluton reported from Pirancheru area near Hyderabad is probably primary in nature as it is not associated with any other sulphides[4]. Here we report the occurrence of molybdenite near Taramatipet, about 20 km east of Hyderabad city, which occurs as disseminated-type porphyry deposit in fracture system within the mafic enclaves surrounded by granitoids (Figure 2). The collected molybdenite samples have been studied by ore petrography and XRD to confirm this occurrence and understand possible genesis.

The study area is a part of eastern Dharwar craton (EDC) which consists of Peninsular Gneisses, plutons of potassic granites and granodiorites[7,8] (2.56–2.52 Ga)[9], and Dharwar Supergroup (2.90–2.54 Ga) represented by volcano-sedimentary greenstone sequences[8]. Recent studies have shown that EDC was cratonized at ~2.5 Ga (ref. 8). Besides tracts of different generations of granitoids, a number of Proterozoic mafic dyke swarms are also emplaced throughout EDC[10–12].

The molybdenite occurrence is encountered near the village Taramatipet (17°21′01″N, 78°39′84″E; see Figure 2). This area comprises granitic plutons and widespread mafic enclaves within the plutons. Widespread mafic injections into the crystallizing 2.56–2.52 Ga calc-alkaline to potassic granite plutons at all exposed crustal levels in the EDC are reported[13,14]. These mafic injections occurred during different stages of crystallization of host magmas. The early injections of mafic melts resulted in the formation of mafic enclaves, whereas late mafic injections resulted in synplutonic mafic dykes[15]. The former condition is observed in the study area. There may be two conditions of mafic–felsic mixing during the early stages; the first is a very early stage of crystallization when both felsic and mafic melts form hybrid magmas leading to the formation of slightly mafic calc-alkaline granitoids, whereas during a slightly later stage, the viscosities of the two magmas may be different and permit only slight mingling[15]. During this later stage mafic enclaves are formed. It is suggested that these mafic injections form the terminal