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Performance Analysis of a Stand-Alone PV System in Yemeni Rural Areas

Musaab Abdulrahman M. Al-Maidan*, Katerina Gabrovska-Evstatieva, Nicolay Mihailov

*Mugla Sitki Kocman University, Muğla, Turkey, musaab.almaidan@gmail.com

GOAL OF THE STUDY

Yemen is one of the developing countries facing electricity shortages at the present time. Approximately 66% of the population live in rural areas. 41% of them are not connected to the public electricity grid where access to the local grid is impossible. Those who have access to the electrical grid receive distributed, unreliable, and intermittent supplies. Furthermore, extending the power grid to some rural areas is not economically feasible. The presently conventional solutions like diesel generators have drawbacks, such as being expensive, high fuel cost, need for maintenance, they are noisy, and cause severe environmental issues.

The principal point of this study is to help in designing a standalone PV system for a typical rural house in Yemen to meet the domestic load. In rural areas the approximate daily load to ensure electricity for lighting and supplying power to the electrical equipment with low consumption is 5-7 kWh. Since in rural areas both air condition and heaters are not used, natural gas and wood are utilized for cooking. Therefore, the load is quite small.

MAIN RESULTS FROM THE STUDY

The object of the investigation is a rooftop standalone system, which is not connected to the electricity grid. It includes solar modules, batteries, controllers, and inverter as main components. A block-diagram of the stand-alone PV system was created in the PVsyst 7.2 software. A typical load profile is chosen (Table 1)

Table 1. PARAMETERS OF THE LOAD

Cnt	Appliance	Daily use, $h.day^{-1}$	Power, W	Daily energy, $Wh.day^{-1}$
10	LAMPS (LED or Fluo)	8.5	5	425
1	FRIDGE SAMSUNG	24	100	2400
1	TV and RECEIVER	3.5	302	1057
1	WASHING MACHINE	1	500	500
2	PHONE CHARGER	4	12	96
1	LAPTOP CHARGER	3	45	135
1	INTERNET MODEM	24	12	288
			Total:	4901

The designed PV installation includes:

- Battery set: The recommended batteries for this system are two 250 Ah, 12 volts each, with a total capacity of 500 Ah. They are connected in series, which means their operating voltage is 24 V. They have 96A maximal charging current and 33A discharge current.
- PV array: Four mono PV modules of 250 Wp, 27V, were chosen to satisfy the required energy. They are connected in parallel, therefore the rated output voltage is 27 V and the rated power – 1000 W.

It's yearly solar fraction average is estimated to be 97.2%, where the lowest values were obtained for July and August (86%) due to the high temperature of the PV modules, which reduces their efficiency. In the remaining ten months, the SF value is 100%.

The normalized production of the installation (excluding the losses) is presented in Fig. 1.

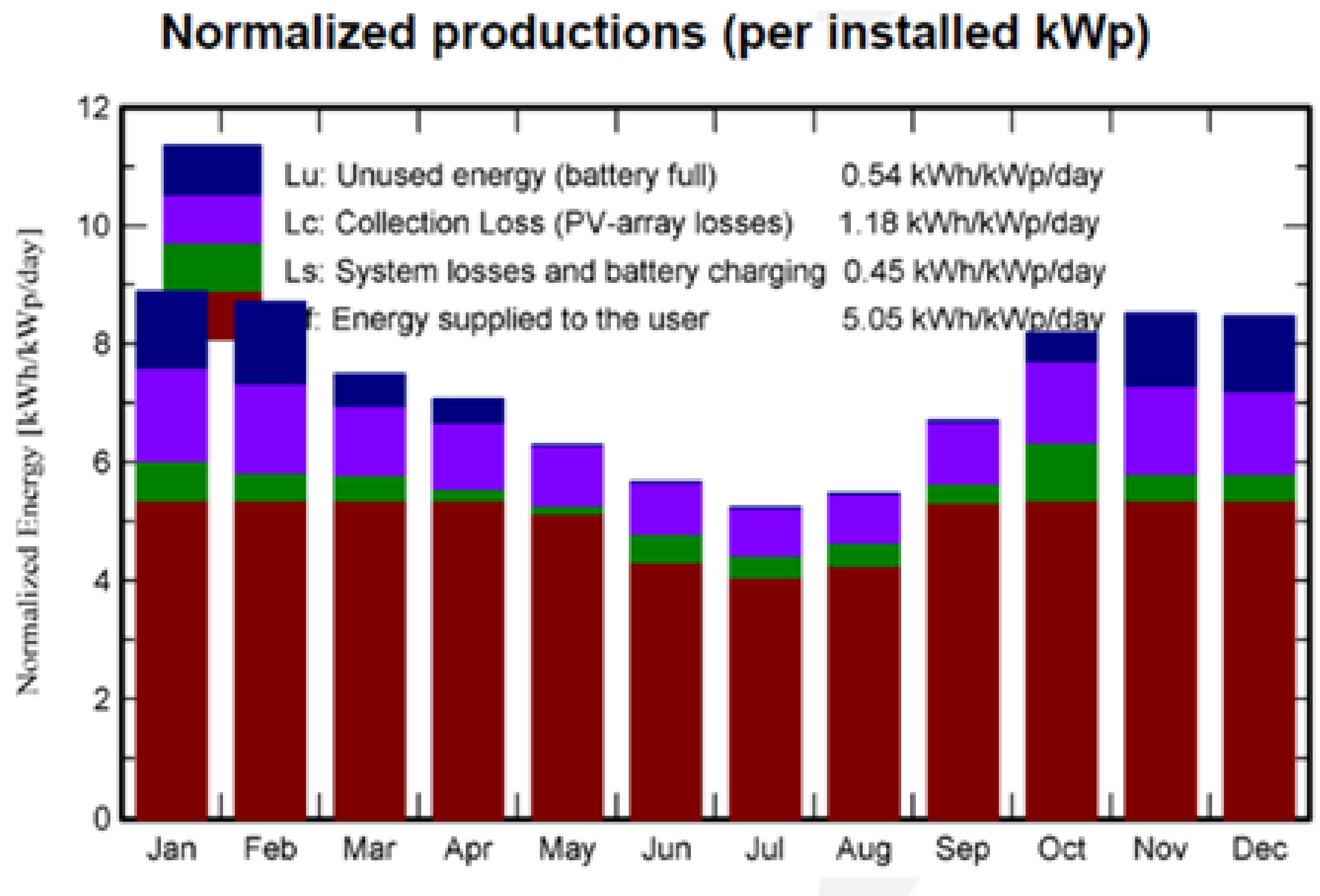

Fig. 1. Figure caption

CONCLUSIONS

The main results from the performed design and analysis could be summarized as follows:

- The performance ratio of the system has a maximum during the summer months, which is caused by the higher solar radiation in May and June;
- The solar fraction is close to 1 with exception of the summer months of June, July and August, which can be explained with the higher ambient temperature.
- The total power loss of the system is approximately 30.6%. Its annual input is 2539 kWh/m^2 energy annually, the output is 1763 kWh/m^2 and the lost energy is 776 kWh/m2. The energy losses are mainly caused by unused energy, as well as losses due to high temperature, ohmic losses, etc. The power losses are higher during the summer months, which is caused by the high ambient temperature. It should be noted that the highest energy output does not occur during the highest available radiation, which indicates there are other important factors.