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## Investigation on the Potential Application of Grid-connected PV System for Food Cold Storage By I Nyoman Suamir

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Investigation on the Potential Application of Grid-connected PV System for Food Cold Storage Nyoman Suamir a, Wayan Temaja, Putu Sastra Negara b, and Made Ery Arsana c Mechanical Engineering Department, Politeknik Negeri Bali, Campus Street, Kuta Selatan, Badung, Bali 80364, Indonesia Keywords: PV System, Energy Generation, Solar Cold Storage and Renewable Energy. Abstract: The paper presents investigation on a small size solar cold storage built at Politeknik Negeri Bali. The solar cold storage comprises a grid-connected PV system and a cold storage using R290 with power input specified for 2.5 kW. The investigation includes potential of renewable energy generation, cold storage energy demand, grid energy imported and renewable energy exported. The PV system is specified for a peak capacity of 3.1 kW. Average instant AC power generation during the day is 1.66 kW with maximum power generations as high as 2.55 kW. Daily renewable energy generation in the selected highest day can reach 18.5 kWh. The investigation results also showed the cold storage consumed 39.8 kWh electricity in a day. During the day (PV production time), the cold storage requires for about 17.5 kWh which is lower than the energy generated from the PV system. However, the cold storage still needs imported energy due to off and defrost cycles. It is about 69% renewable energy generation can be applied but the rest of 31% must be exported to the grid. This results show the use of renewable energy storage system can improve the utilization of renewable energy to drive the cold storage. 1 INTRODUCTION Application of integrated photovoltaic (PV) system for commercial buildings is exceptionally favourable, specifically in the sunny climate regions. The usage of the PV systems is cost-effectively more attractive due to their investment cost become cheaper and cheaper. The PV system can provide a substantial effect on countryside growth. PV systems can be applied for varies applications from very small-scale to mid-scale uses (Foley, 1995; Braun and Rüther, 2010; Feron, 2016). Indonesia also has prospective use of solar PV system in commercial building sector as well as in the rural area. As a tropical country, Indonesia including Bali Island has intensive value of solar irradiation ranging from 4.6 kWh m-2 to 7.2 kWh m-

2. This proofs that the country has high potential solar energy sources (Rumbayan, 2012; Santika et al., 2016). On the other hand, the utilization of solar energy in Indonesia is only 0.03% of its total energy use which accounted for 2.78 MW. It is about 0.41% of the total a https://orcid.org/0000-0003-0594-7511 b https://orcid.org/0000-0002-1028-070X c https://orcid.org/0000-0002-6647-6621 renewable energy utilization (Yudiartono, 2018). This shows that the segment of solar energy use in Indonesia is insignificant. However, there is still a shortage of publications regarding the prospective and limitations of solar PV implementation, specifically for food preservation such as cold storage. An investigation on solar refrigeration systems has testified that such systems could be used where national grid is not continuously available or regions are not suitably electrified whereas refrigeration demand is life-threatening (Aktacir, 2011). Elias and Yilma (2019) reported that for simulation investigation analysis and simulation of a solar PV driven refrigeration system utilizing a compressor with variable speed system. Energy performance of a solar PV refrigeration can be evaluated. However, most of the publications on solar PV refrigeration system are based on absorption cycle system or adsorption refrigeration cycle as published in several researches (Suamir, 2014; He et al., 2019; Suamir, N., Temaja, W., Negara, P. and Arsana, M. Investigation on the Potential Application of Grid-connected PV System for Food Cold Storage. DOI: 10.5220/0010951800003260 In Proceedings of the 4th International Conference on Applied Science and Technology on Engineering Science (iCAST-ES 2021), pages 704-709 ISBN: 978-989-758-615-6; ISSN: 2975-8246  Bellos and Tzvanidis, 2017; Fellah et al., 2019; Wang et al., 2018). This study presents an innovative integrated solar PV technology which is utilized to power a cold storage refrigeration system. Indonesia weather data, more specifically Bali Island weather data is applied. According to Husband et al. (2020), the country and region have the prospect of using solar PV food refrigeration systems. The country also requires enormous funds for energy efficient technology that can increase the growth of food cold storage infrastructure with various capacities. The refrigeration demand is due to the country is undergoing an imbalance food supply and demand. This is one of the challenges in improving food security and food sustainability of the country. Indonesia is well-known as the second highest fishery producer in the world (FAO, 2016). Meanwhile, the growth of food cold storage for the fishing industry is not suitable. Indonesia is also a country within the list of low index food cold storage (IARW, 2016). In 2016, Indonesia had food cold storage capacity about 12.3 million m3 (FAO, 2016; IARW, 2016). This paper that present investigation results on the potential application of grid-connected PV System for food cold storage may encourage the development of food cold storage infrastructure in Indonesia. 2 MATERIALS AND METHODS 2.1 The Grid-connected PV System The grid-connected PV system is situated at Politeknik Negeri Bali in Bali Island, Indonesia. The solar PV system comprises: solar power generation, electrical power distribution, connection to the grid and protection devices. The solar power generation system consists of 10 solar PV panels. Each PV panel has a 310 Wp capacity. The solar PV generation system also includes a grid inverter of 5 kW maximum capacity. Specification of the solar PV panel can be seen in Table 1. The panel has a peak power of 310 Wp at maximum voltage 33 V and current 9.4 A. Each PV panel has 60 mono-crystalline silicon cells. The mono-crystalline cell has higher efficiency compared with the polycrystalline PV cell. The cell size is 0.150 m x 0.150 m each, hence area of each panel becomes 1.35 m2. The cell has maximum efficiency of 22.96%. The electrical power distribution and grid connection systems are accomplished with some breakers and one energy meter to record renewable energy generation and also a digital power meter for recording energy exported to the grid. The solar PV system also incorporates protection devices to prevent damages from lightning. The solar PV system utilizes a fixed array installation system with 17° tilt angle and the azimuth direction

facing to the north. The tilt angle used is an optimum tilt angle based on solar radiation conditions in Bali Island. The optimum tilt angle is from 10° to 18° with azimuth direction to the north (Sugirianta et al., 2020). Table 1: Specification of the 310 Wp solar PV panel. Parameters Value Maximum power Pmax (Wp) 310 Voltage at Pmax (V) 33 Current at Pmax (A) 9.4 Open circuit voltage (V) 40.30 Short circuit current (A) 9.96 Test condition (W m-2) Temperature test (°C) Panel size (mm) Weight (kg) Test condition (W m-2) Temperature test (°C) Cells type Cell size (m x m) Number of cells 1000 25 1640 x 990 x 35 19 1000 25 Mono-crystalline silicon 0.150 x 0.150 60 This value is in agreement with the solar PV system array in the regions of East, Central and West Java. The optimum tilt angle of the solar PV array for azimuth direction to the north of the regions are respectively from 0º to 40º, from 1º to 34º at optimum 18º and 10º (Handoyo, 2013). 2.2 The Food Cold Storage System A lab size innovative cold storage has been built in Politeknik Negeri Bali. The cold storage is a sustainable refrigeration platform for frozen food incorporating: Grid-connected solar PV power system, energy-efficient refrigeration system with low emission refrigerant, instrumentation and monitoring systems. The schematic of the developed food cold storage system is shown in Figure 1. In order to achieve a complete performance testing, the cold storage test system is completed with proper instrumentation and monitoring systems which comprise temperature and pressure sensors, RH sensors, flowmeter, and power analysers. For the solar PV panels, instrumentation will include voltage, current, power, solar irradiation, and surface temperature measurements. iCAST-ES 2021 - International Conference on Applied Science and Technology on Engineering Science Grid-tide solar PV Ssstem Innovative control system 10 x 310 Wp Evaporator controller Grid-tide inverter AC SPD with Breaker Supply electricity from grid, 220 VAC StV T EEV T T T T Evaporator High density PU panel 100 mm DC SPD with Breaker Condensing unit controller Power analyser T Condenser T ShV F/D SG SV FM $m$? T Cold room system PSH/L 220 VAC M StV Compressor T ShV Data logger Computer Legend: Pressure T Temperature Refrigeration system Instrumentation and monitoring transducer sensor system F/D = Filter dryer; SG = Sight Glass; SV = Solenoid Valve; ShV = Shut-Off Valve; StV = Straddle Valve; EEV = Electronic Expansion Valve; PSH/L = Pressure Switch High/Low; FM = Flowmeter; SPD = Surge Protective Device; PU = Polyurethane Figure 1: The food cold storage system comprises refrigeration, cold room, innovative control, grid-tide solar PV, instrumentation and monitoring systems. The output signals from the instrumentation devices are logged by a data logging system which comprises data acquisition modules and a recording and display system. The data acquisition modules utilise the Datascan 7000 series from MSL (Measurement System Ltd.) which include a Datascan measurement processor 7320 and expansion modules 7020. Each Datascan module contains 16 differential input channels, individually configurable for voltage and thermocouple measurements. Corriolis flowmeter was used to measure refrigerant flow rate in the system. 2.3 Experimental Test Methods The solar PV system incorporates an IoT (Internet of Things) based monitoring system which are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. A comprehensive data (hourly, daily, monthly and yearly) related to system performance can be accessed through the internet. Recorded data in 2019 and 2020 were used for the analysis. Some data were also recorded on site which include solar radiation, energy generated and exported to the grid. Solar irradiance was measured by using a Lutron Solar Power Meter SPM-1116SD of 10 W m-2 accuracy. For irradiance lower and higher than 1000 W m-2 the resolutions can reach 0.1 W m- 2 and 1 W m-2 respectively. The energy meters have measurement accuracy in the range of ±1%. Recorded data from the measurement system were processed using spread sheet software and analysed. Performance parameters of the solar power supply system such as solar power generation, efficiency and power consumption by the cold storage were calculated and presented. Further calculations and graphs manipulation were processed by using spread sheet program. 3 RESULTS AND DISCUSSION 3.1 Renewable Energy and Power Generation Figure 2 shows monthly electrical energy generation from the PV system for one year in 2020. The figure also shows one-year variation of the PV system capacity factor. Monthly electrical energy generation varies from 300 kWh to 499 kWh with average of 412 kWh. Annual energy generation of the PV system can reach 4.95 MWh. Utilization potential of the PV system stated as capacity factor can reach annual average value of 38.7%. Maximum monthly utilization potential with capacity factor value of 46.1% occurs in August, while minimum value 26.1% happens in December. Figure 2: Monthly renewable energy generation for the investigated year 2019 and 2020. Figure 3 shows investigation results involving instant AC solar electrical power generation, cumulative AC energy generation, DC power and DC energy. The fluctuation of AC electrical power generation during the lowest production day in December can be seen in Fig. 3. Time of production is about 10 hours starting from 6.30 in the morning to 4.30 in the afternoon. Average instant power generation during production period is 274 W and maximum power is 741 W. While cumulative AC electrical energy generation in the selected lowest day of production is only 2.82 kWh. Figure 3 also shows variation of the AC power generation together with electrical energy generation during production period of the selected day in August (the highest production month). Time of production is one hour longer than the lowest day in December which is 11 hours starting from 6.40 to 17.40. The average instant AC power generations during production period are 1662 W. While the maximum AC power generations, which occur at around 12 o'clock, can reach as high as 2552 W and cumulative energy generation can be 18.5 kWh. 3.2 Energy Consumption of the Food Storage The variation of power consumption of the food cold storage in one day is presented in Figure 4. The average power consumption is about 2.4 kW. The figure also shows on and off cycles due to thermostat regulation and defrost cycles. 3.3 The Potential of the Grid-connected PV System applied for the Food Cold Storage Figure 5 shows power consumption of the food cold storage in 24 hours' test at steady operation with 15 minutes off cycle due to defrost in every 4 hours. The investigation results also showed the cold storage consumed 39.8 kWh electricity in a day. Daily renewable energy generation in the selected highest day can reach 18.5 kWh. The investigation results Figure 3: AC electrical power generation during the highest production day in August and the lowest production day in December 2020. iCAST-ES 2021 - International Conference on Applied Science and Technology on Engineering Science 4000 3500 Cold storage power (W) 3000 Power (W) 2500 2000 1500 1000 500 0 0 2 4 6 8 10 12 14 16 18 20 22 24 Time (hours) Figure 4: Power consumption of the food cold storage in 24 hours' test at steady operation with 15 minutes off cycle defrost in every 4 hours. 4000 3500 Cold storage power (W) PV Power Generation (W) 3000 Power (W) 2500 2000 1500 1000 500 0 0 2 4 6 8 10 12 14 16 18 20 22 24 Time (hours) Figure 5: The potential use of grid connected PV system to powering the food cold storage. also showed the cold storage consumed 39.8 kWh electricity in a day. During the day (PV production time), the cold storage requires for about 17.5 kWh which is lower than the energy generated from the PV system. However, the cold storage still needs imported energy due to off and defrost cycles. It is about 69% renewable energy generation can be applied but the rest of 31% must be exported to the grid. This results show the use of renewable energy storage system can improve the utilization of renewable energy to drive the cold storage. 4 CONCLUSIONS A lab size innovative cold storage has been built in Politeknik Negeri Bali. The solar cold storage comprises a grid-connected PV system and a cold storage using R290 with power input specified for 2.5 kW. The PV system is specified for a peak capacity of 3.1 kW. Average instant AC power generation during the day is 1.66 kW with maximum power generations as high as 2.55 kW. Daily renewable energy generation in the selected highest day can reach 18.5 kWh. 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