ANALYSIS OF POLYCRYSTALLINE SOLAR PANEL ENERGY SUPPLY IN SERIES AND PARALLEL CIRCUITS FOR ON-GRID PLTS

I Nyoman sugiarta
Electronic Engineering, Bali State Polytechnic
Jimbaran, Bali, 80361, Indonesia, Phone: + 62-361-701981, Fax: + 62-361-701128
sugiartaelektro@pnb.ac.id

Abstract. This on-grid PLTS utilizes renewable energy in the form of solar energy combined with PLN's power grid. One of the most basic needs in the education process on campuses, schools, both private and government especially during the day is the use of LCDs, practical equipment, computers / laptops and air conditioners. From the research results of Polycrystalline Solar Panel Energy Supply Analysis in Series and Parallel Circuits for on-grid PLTS using smart grid inverters, the average electrical energy produced by two solar panels arranged in series in various weather is 0.3 kWh/day while in parallel circuits 0.2 kWh/day. The graph of electrical energy (kWh/day) in series is higher than in parallel circuits. The average electrical energy produced by one solar panel of 200 Wp on an on-grid system in various weather is 0.187 kWh/day while for two 100 Wp solar panels arranged in series is 0.336 kWh/day. The graph of electrical energy produced by two 100 Wp solar panels in a series circuit is higher than one 200 Wp solar panel. For on-grid systems two 100 Wp solar panels arranged in series are better than one 200 Wp solar panel. It can be concluded that the series circuit is able to obtain maximum electrical energy in the on-grid system by using a smart inverter compared to two 100 Wp solar panels arranged in parallel and one 200 Wp solar panel.

Keywords: PLTS on-grid, Series Circuits, Parallel Circuits, Smart Grid Inverters, Polycrystalline Solar Panels

I. Introduction

This enormous potential of solar energy can be utilized as electrical energy with the help of photovoltaic technology, which is technology that is able to convert sunlight directly into electrical energy. The use of photovoltaic technology as a power plant in Indonesia is known as PLTS (Solar Power Generation). PLTS is a power plant that fully utilizes sunlight as an energy source. Types of solar cells include monocrystalline and polycrystalline. Polycrystalline types have lower efficiency and greater dimensions compared to monocrystalline types. However, this type can produce electrical energy in cloudy weather conditions and has a lower price so it is widely used in the market. [1] On-grid PLTS is one of the main examples of generating systems that are properly applied to areas that are already covered by large-scale and small-scale generating systems. This on-grid PLTS utilizing renewable energy in the form of solar energy combined with existing power networks such as diesel or other existing energy sources. Solar energy is converted into electrical energy through photovoltaic modules that are directly channeled to the electricity network that was previously supplied by the Diesel Generator Set or other source, so that it becomes a more efficient and reliable system to be able to supply electrical energy needs during the day. One of the most basic needs in the education process on campuses, schools, both private and government especially during the day is the use of LCDs, practical equipment, computers / laptops and air conditioners. To support a government program that launches "green energy" and energy savings or energy efficiency, the authors plan the study of Polycrystalline Solar Panel Energy Supply Analysis in the Series and Parallel Series for on-grid PLTS.

II. Methodology

Monthly average insulation on horizontal surfaces at the indicated GMT (kW / m ^{2} / day) data for Denpasar, Bali [2] as table 1.

Table 1. Monthly average insulation for Denpasar, Bali

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
22-year average	4.93	5.04	5.43	5.39	5.19	4.84	4.79	5.33	5.95	6.19	5.67	5.28

The lowest isolation occurred in July of 4.79 (kW/m ^{2} /day) and the highest in October was 6.19 (kW/ m ^{2} /day). The average insulation measured is 5.335833 (kW/ m^2 /day) The data in the table above is used as the basis for making a research flow chart like Fig1 below:

A. Research Flow Chart

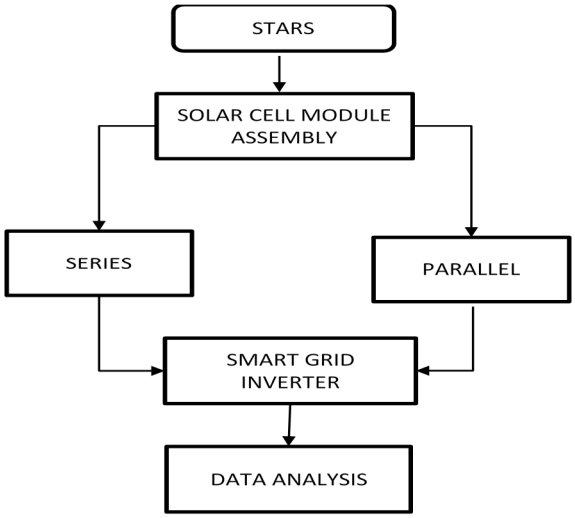

Fig1. Research Flow Diagram.

B. Tools and materials used

1. 100 Wp and 200 Wp Polycrystalline solar panels.
2. Solar Smart Microinverter SG 600 (Model SG600 MD).
3. Data Box - Data Collector (Model DataBox24G).
4. High-precision watt meter and power analyser 150 A.
5. Digital AC Wattmeter 0-3680 W.
6. MC4 Solar Panel PV Cable Connectors
7. 20m Solar Cell Green Power cable.
8. 20m PLN cable 3x2.5 mm.

III. Results and Discussion

A. Research Objectives and Location

This research was conducted at Kodya Denpasar, Bali using 100 WP polycrystalline solar panels arranged in series and parallel. Kodya Denpasar is located at coordinates 8.67 south latitude and 115.21 east longitude. This study aims to determine the difference in electrical energy produced by solar panels arranged in series and parallel on the PLTS on-grid system.

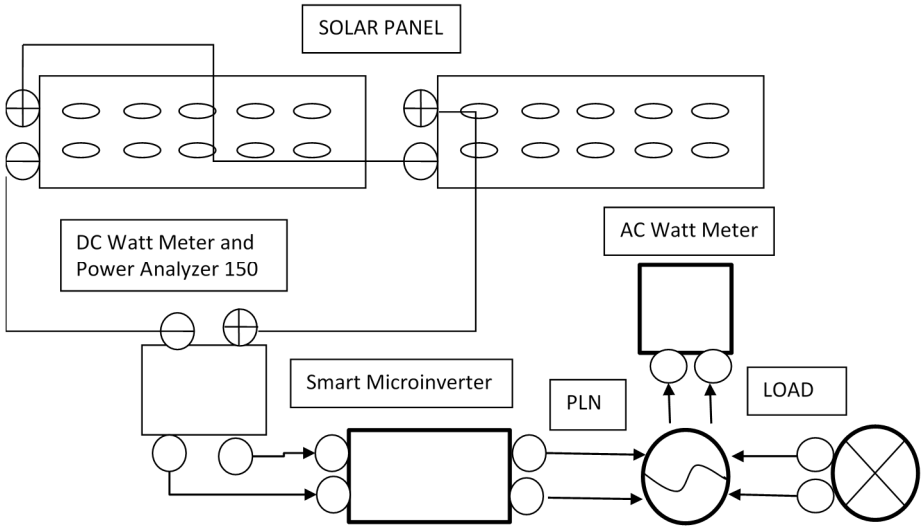

Fig 2. PLTS Series on-grid

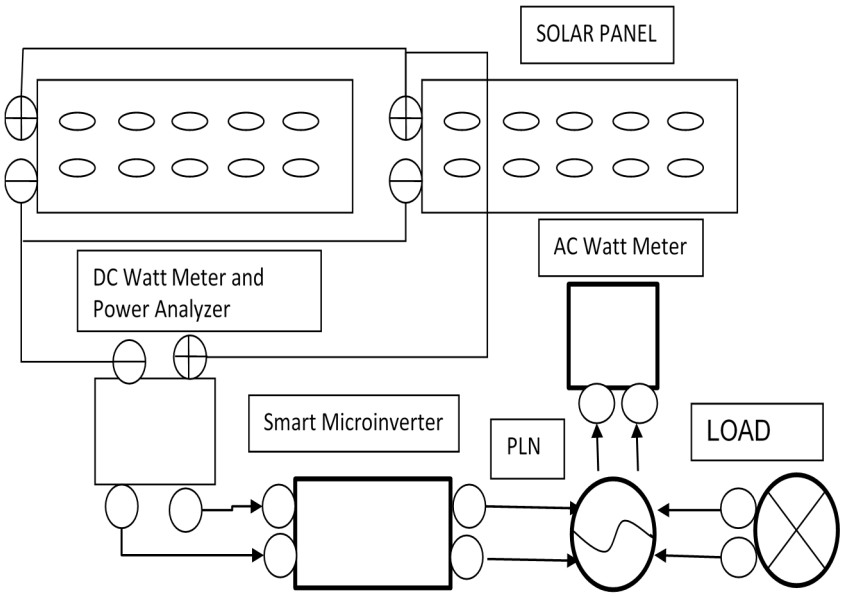

Fig 3. PLTS on-grid Parallel Circuit

Table 2. 100 Wp Solar Panel Specifications

Item	Value
Model	SP100-18P
Rated Maximum Power	100W
Cell Efficiency	16.93%
Open Circuit Voltage (Voc)	21.8 V
Short Circuit Current (Isc)	6.05 A
Voltage at Maximum Power (Vmp)	17.8 V
Current at Maximum Power (Imp)	5.62 A
Power Tolerance	±3%
Max System Voltage	1000 V
Series fuse rating(A)	12
Number of bypass diode	2
Operating temperature	-4 ^{0}C to 85 ^{0}C
Cell Technology	Poly-Si
Dimension (mm)	1000x670x30mm

Table 3. 200 Wp Solar Panel Specifications

Item	Value
Model	GH200P-20
Rated Maximum Power (Pm)	200W
Power Tolerance	3%
Open Circuit Voltage (Voc)	30.87 V
Short Circuit Current (Isc)	8.51 A
Voltage at Maximum Power (Vmp)	24.72 V
Current at Maximum Power (Imp)	8.10 A
Max System Voltage	1000 V
Normal Operating Cell Temp (NOCT)	47± 2 ^{0}C
Number of bypass diode	2
Operating temperature	-40 ^{0}C to 85 ^{0}C
Cell Technology	Poly-Si
Dimension (mm)	1320x992x35mm

B. Data analysis

Theoretical Energy Results

The output power generated from the solar panel can be calculated based on the specifications of the solar panel used, and also by using the equation: [3]

The average insulation measured in Kodya Denpasar is 5.335833 (kW/ m^2 /day)

The area of solar panels used in the research is 0.67 m^2 (100 Wp) and 1.3 m^2 (200Wp)

The efficiency of the solar panel $\eta = 0.1693$

Then the solar panel output power of 100 Wp is calculated by the formula:

P (watt peak) = Area x PSI x η

P (watt peak) = 0.67 [m^2] x 2 panels x 5.34 [kWh/m^2 /day] x 0.1693 PG = 1.216 [kWh/day]

P (watt peak) = 36.48 [kWh / month]; PG = 443.84 [kWh/year]

Then the solar panel output power of 200 Wp is calculated by the formula:

P (watt peak) = Area x PSI x η

P (watt peak) = 1.3 [m^2] x 1 panel x 5.34 [kWh/m^2 /day] x 0.1693 PG = 1.175 [kWh/day]

P (watt peak) = 35.26 [kWh / month]; PG = 423,101 [kWh/year]

Information:

Area = Area of solar panels

PSI (Peak Solar Insulation) = Average solar insulation

η = solar panel efficiency

Empirical Energy Results

Electrical energy generated from two solar panels arranged in series and two solar panels arranged in parallel at the same time as table 4 and fig.4 below:

Table 4. Electrical energy produced by series solar panels and parallel solar panels

HOUR	DATE	WEATHER	PARALLEL SOLAR PANEL 100 WP (KWH)	SERIES SOLAR PANEL 100 WP (KWH)
10.00-14.00	05 June 2020	Cloudy Rain	0.04	0.05
09.00-14.00	06 June 2020	Sunny Cloudy	0.22	0.37
09.00-14.00	07 June 2020	Sunny Cloudy	0.22	0.37
09.00-14.00	08 June 2020	Sunny Cloudy	0.22	0.41
09.00-14.00	09 June 2020	Sunny Cloudy	0.22	0.41
08.00-14.00	10 June 2020	Sunny Cloudy	0.24	0.41
08.00-14.00	11 June 2020	Sunny Cloudy	0.24	0.43

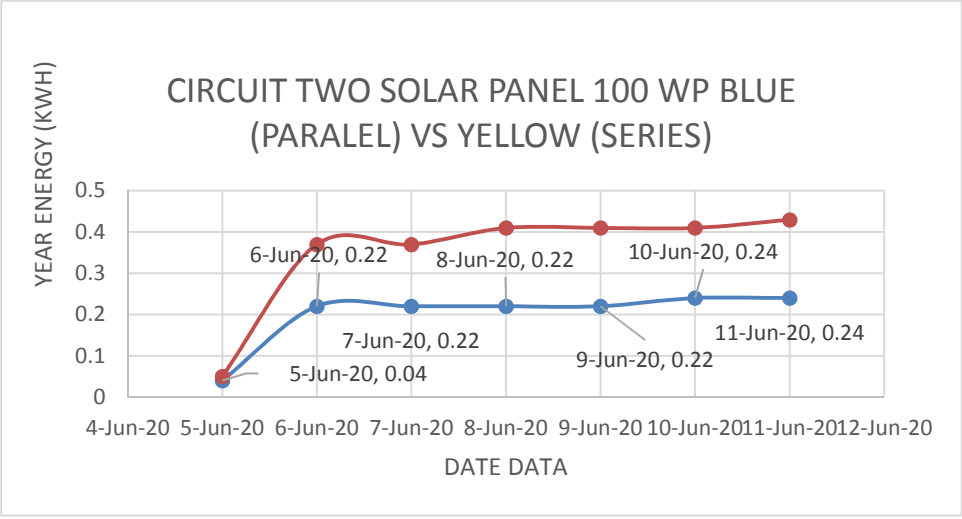

Fig.4. Graph of electrical energy produced by two series solar panels and two parallel solar panels

The average electrical energy produced by two solar panels arranged in series on an on-grid tie system in various weather is 0.3 kWh per day while for solar panels arranged in parallel is 0.2 kWh. In figure 3 can be seen the graph of electrical energy produced by solar panels in series is higher than solar panels arranged in parallel. For on-grid series solar panel systems, it is better than parallel circuit solar panels. It should also be remembered that the installation of solar panels in the series of allowable voltage limits does not exceed the smart grid inverter voltage limits used. Electrical energy generated from one 200 Wp solar panel vs. two 100 Wp solar panels arranged in series at the same time as table 5 and fig.5 below:

Table 5. Electricity energy produced by one solar panel 200 Wp vs two solar panels 100 Wp series.

HOUR	DATE	WEATHER	ONE SOLAR PANEL 200 WP (KWH)	TWO SERIES SOLAR PANEL 100 WP (KWH)
09.00-14.00	12 June 2020	Sunny Cloudy	0.37	0.49
09.00-14.00	13 June 2020	Sunny Cloudy	0.12	0.28
09.00-14.00	14 June 2020	Sunny Cloudy	0.11	0.23
09.00-14.00	15 June 2020	Sunny Cloudy	0.12	0.27
09.00-14.00	17 June 2020	Sunny Cloudy	0.15	0.36
08.00-14.00	18 June 2020	Sunny Cloudy	0.23	0.35
08.00-14.00	19 June 2020	Sunny Cloudy	0.21	0.37

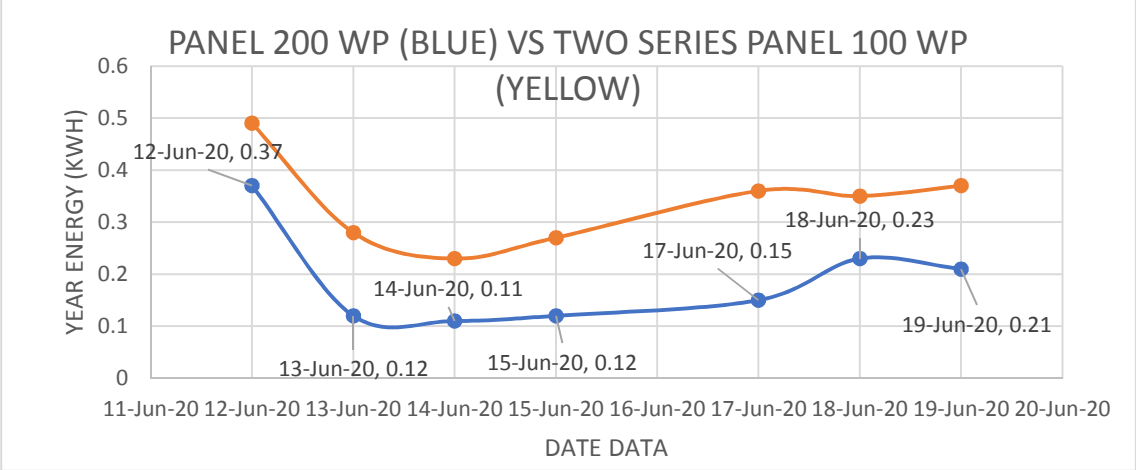

Fig.5. Graph of electrical energy produced by one solar panel 200 Wp vs two solar panels 100 Wp series

The average electrical energy produced by one solar panel is 200 Wp in an on-grid tie system in various weather 0.187 kWh per day while for two 100 Wp solar panels arranged in series is 0.336 kWh. In figure 5 can be seen a graph of electrical energy produced by two 100 Wp solar panels in a series circuit higher than one 200 Wp solar panel. For on-grid systems two series 100 Wp solar panels arranged in series are better than one 200 Wp solar panel. It should also be remembered that the installation of solar panels in the series of allowable voltage limits does not exceed the smart grid inverter voltage limits used.

IV. Conclusion

The average electrical energy produced by two solar panels arranged in series on an on-grid tie system in various weather 0.3 kWh per day while for solar panels arranged in parallel is equal to 0.2 kWh. The graph of electrical energy produced by solar panels in series is higher than solar panels arranged in parallel. For on-grid systems the series of solar panel series is better than parallel circuit solar panels. The average electrical energy produced by one solar panel is 200 Wp in an on-grid tie system in various weather 0.187 kWh/day while for two 100 Wp solar panels arranged in series is 0.336 kWh. The graph of electrical energy produced by two 100 Wp solar panels in a

series circuit is higher than one 200 Wp solar panel. For on-grid systems two series 100 Wp solar panels arranged in series are better than one 200 Wp solar panel. It can be concluded that the series circuit is able to get maximum electrical energy in the on-grid tie system by using a smart inverter. It should also be remembered that the installation of solar panels on this circuit allowable voltage limits do not exceed the smart grid inverter voltage limits that are used. The theoretical energy calculation of two solar panels 100 Wp produces 1,216 [kWh/day], while the electrical energy results of two solar panels arranged in series empirically get an average yield of 0.3 - 0.336 kWh/day. The theoretical energy calculation of 200 Wp solar panels yields 1,175 [kWh/day], while the energy yield empirically yields an average of 0.187 kWh/day

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