Design Of Electricity Energy Sources In University Of PGRI Semarang Using Off-Grid Solar Panel Systems

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Abstract. The source of electricity in each university building in PGRI Semarang is obtained from each distribution transformer or power transformer. The power transformer used to distribute electricity in the central building (GP) has a capacity of 400 KVA, while the power transformer used in the main building (GU) has a capacity of 160 KVA. In the previous study, identification of the quality of electrical power in the PGRI University Semarang building, obtained a low power data factor and a large electrical network harmonics. The problem was solved by designing and installing bank capacitors and harmonic filters. To avoid dependence on PLN electricity and not using a generator when PLN electricity goes out, the source of electrical energy is designed by using solar energy sources through Photovoltaic. Solar Panel as an important component of solar power plants, converts sunlight into electricity. In designing off-grid solar panel systems it is only used at night or when PLN electricity goes out. In the design in the Central Building (GP) four solar panels and a battery unit are needed. Each solar panel unit consists of 14 solar panels and a battery unit consisting of an array of 110 batteries. The simulation results show that the simulation output power is almost the same as the design output power, which is 280,045 Watts. This shows the results of the design can be used to make electricity resources using solar panels. The inverter's output voltage is also in accordance with the voltage used in the load of the house, which is 220V AC.

1. Introduction
The high demand for electricity causes increased dependence on electricity, while the electricity source in Indonesia is increasingly decreasing, especially those that use fossil energy or non-renewable energy such as oil, coal and gas. In the study of identification of electrical quantities which include current, voltage, power factor, electric power and harmonic distortion (THD). Based on the results of the study there are several problems, namely the power factor that is still low, the imbalance of voltage (unbalanced voltage) and voltage increases (over voltage), unbalanced load sharing, and harmonics in the electricity network is quite large. The total percentage of harmonic distortion (% THD) of the central building is 67.9 and the main building is 76.3. In this study problem solving was emphasized in the issue of power factor and harmonics [1]. In DC network systems micro grid battery storage units are used to assist the main source of renewable energy (PV array) in providing stable voltage on the DC bus. Micro grid storage systems play an important role in providing services on demand. The lithium-ion batteries are used in this design, because these batteries have high energy density. In the micro-grid design is used three units of PV arrays and each unit consists of two PV arrays and two batteries. Battery units are used for storage of PV array sources and single phase grid AC. The PV
array unit provides 22.8 V output voltage and the battery unit provides 22.78 V output voltage. Boost converter increases the voltage of the PV array and battery unit to a DC bus of 48 V. The PID controller is effectively used boost converter in raising or lowering the voltage. The advantage of using two battery storage systems is that if one unit is not sufficient to provide a voltage to the DC bus, then the battery unit on the AC grid side will also rapidly provide a voltage to the DC bus [2].

CLLC-type DC transformer (CLLC-DCT) is very popular in the hybrid AC/DC microgrid thanks to its high-power density advantage and good bidirectional power transfer capacity. In the hybrid AC/DC microgrid, the open-loop control is always utilized by the CLLC-DCT to cooperate with the bidirectional interlinking converter to realize the power and voltage conversion between the AC and DC bus. To solve this problem, a robust circuit parameters design scheme is proposed for the CLLC-DCT in this paper. With the proposed scheme, the designed CLLC-DCT exhibits good power transmission and voltage regulation ability in the hybrid AC/DC microgrid even when its actual inductors / capacitors values vary with the practical power and temperature [3][4]. This research presents a three-phase bidirectional DCAC converter suitable for operating as an interface between an energy storage system (ESS) based on a battery bank and an isolated microgrid with distributed generation. A control strategy is proposed where the DC-DC stage regulates the DC link voltage level while the DC-AC controls the three-phase output voltage and frequency, therefore acting as a grid-forming converter (GFC). A modified droop strategy is implemented to control the power generated inside the microgrid to avoid overcharging the ESS. Voltage unbalance reduction capabilities were implemented in order to deal with unbalanced loads. A 15kW prototype was successfully built and tested in different situations and the experimental results are shown [5].

This research investigates a specific type of converter based general interface, which can be used for AC microgrids integrating to the active distribution network. The interface, a Back-to-Back (BtB) converter, is used to connect the AC sides of the distribution network and the microgrid. The common DC link of the BtB converter is connected to one terminal of a bidirectional DC-DC converter while the other terminal of the DC-DC converter is connected with an energy storage system. By adopting proposed coordinated control within the interface, the distribution network and the microgrid can be decoupled in terms of the AC voltage and current. Furthermore, this interface can provide enhanced voltage stability and high power quality in case of severe disturbances on the AC side. Hence, the microgrid can be integrated into the distribution network in a safe and flexible way. A testing system is built using RSCAD and the structure and control strategy proposed in this paper are verified through the Real Time Digital Simulator (RTDS) [6][7]. This research presents a closed loop digital controller of boost converter for renewable energy source like photovoltaic (PV) cell. PV cell efficiency varies according to weather conditions. The control loop is analyzed and the digital controller is designed using PI controller. The closed loop taking the sample values and continuously comparing reference signal with the output current and voltage to maintain a maximum constant output voltage. Even by changing the load value, output voltage and current kept constant. Also PWM switching frequency of MOSFET increases the performance of converter [8].

A novel multiple-input bidirectional DC-DC power converter to interface more than two dc sources of different voltage levels. Converter can be used to operate in both the buck and boost modes with bidirectional power control. It is also possible to independently control power flow when more than two sources are actively transferring power in either direction. This paper presents a power converter topology based on three switching legs of a standard 3-phase inverter module. The operation, analysis and design of the converter are presented with different modes of power transfer. Proposed converter is demonstrated for fuel cell vehicle application using real-time hardware-in-the-loop system. Results for a 5kW system are presented validating the theoretical analysis [9]. Due to the attractiveness of the Vehicle to Grid (V2G) technology, the present study focuses on designing a bidirectional DC charger of an EV. The DC-DC converter used in this study is the Dual Active Bridge converter. A design methodology as well as a control strategy is proposed [10][11]. In order to address the voltage control problem in a dc distribution system (dc-microgrid) with renewable sources and energy storage devices, in this research we propose a new Sliding Mode Controller for a dc-dc bidirectional power converter.
to control the dc bus voltage under instantaneous Constant Power Loads (CPLs). This type of loads introduce a destabilizing nonlinear effect on the converter through an inverse voltage term that can lead to significant oscillations in the dc bus voltage. A simplified scheme based on two cascaded converters was considered to validate the proposed voltage controller [12]. The energy generation from the renewable sources such as wind and solar are intermittent in nature. A battery port is mandatory for this purpose. The bidirectional power flow capability through a feedback back path to charge a battery from the load capacitor is also provided. Therefore, the battery is not only charged from the input source but also from the load capacitor. The number of outputs are independent from each other and the battery is charged from the second output. Steady state operation and theoretical analysis of the converter proposed is elaborated [13][14]. In chapter (1) discussed about previous research which is the background of this paper, chapter (2) discusses the PV system and the battery model, chapter (3) research methodology (4) results of research and discussion, and chapter (5) discuss the conclusions of the results of the testing and analysis.

2. Model Of a Photovoltaic System

To understand the PV system can be done by making a model in the form of an equivalent circuit, shown in fig 1. By looking at the equivalent circuit can be derived the PV current equation, in equation 1 [15].

\[ i = i_{ph} - i_s - i_r \]  

(1)

is the current (A) output of solar sell, \( i_{ph} \) is the current (A) which is affected by light intensity, \( i_s \) is current (A) of Shockley diodes, \( i_r \) is current (A) shunt, \( i_o \) is saturation current (A) of PV cells, \( q \) is electron charge (q = 1, 6 \( \times \) 10\(^{-19} \) C), \( k \) is Boltzmann's constant (k = 1, 38 \( \times \) 10\(^{-23} \) J / K), \( n \) is the ideal factor for solar sell, \( T \) is the temperature of solar sell, \( R_{sh} \) is the shunt resistance (Ohm) and \( R_s \) are internal series resistance (Ohm).

![Solar sell equivalent circuit.](image)

The I-V curve is basically affected by changes from two inputs which are solar insolation and array temperature. Practical arrays are composed of several connected photovoltaic cells and the observation of the characteristic the terminals of the photovoltaic array requires the inclusion of additional parameters [16].

\[ I_{ph} = I_{ph0} \left( \frac{S}{S_b} + C_r(T - T_{ref}) \right) \]  

(2)

\[ I_s = I_s \left( e^{\frac{qV_s}{nkT}} - 1 \right) \]  

(3)

\[ i_s = \frac{V_s}{R_{sh}} \]  

(4)

\[ v_s = \frac{V_s}{N_s} + i_s R_s \]  

(5)

The light generated current of the photovoltaic cell depends linearly on the solar irradiation and is also influenced by the temperature according to

\[ I_{ph} = (I_{ph0} + K_i \Delta T) \frac{G}{G_0} \]  

(5)
where $I_{pv,n}$ is the light-generated current at the nominal condition (usually 25 C and 10000W/m2), $\Delta T = T - Tn$ (being $T$ and $Tn$ the actual and nominal temperatures), $G$ [W/m2] is the irradiation on the device surface, and $Gn$ is the nominal irradiation. The diode saturation current $I0$ and its dependence on the temperature may be expressed by equation:

\[
I_o = I_{o0} \left( \frac{T}{T_{ref}} \right)^{ \frac{Q_{eq}}{qEg} } \left( \frac{T}{T_{ref}} \right)^{ \frac{Q_{eq}}{qEg} - 1 } \]

\[
T = T_{ref} + \left( k_s * S \right)
\]

where $Eg$ is the band gap energy of the semiconductor ($Eg \sim 1.12$ eV for the polycrystalline Si at 25 C, and $I0,n$ is the nominal saturation current.

### 3. Research methodology

In the research design of electrical energy sources using solar panels through the following stages:

a. Calculate the load power requirements per hour  
b. Calculating power requirements per day  
c. Calculating the total energy needed  
d. Calculating the number of solar panels  
e. Calculating the number of batteries  
f. Creating a solar panel simulation model  
g. Analyze the need for electricity with solar panels

### 4. Results and Discussion

In the use of solar energy sources for electrical power needs at the University of PGRI Semarang (UPGRIS) based on Figure 2, namely solar panels, charge controllers, batteries, and inverters. The work system used is an off-grid solar panel system, this system only works at night or if the PLN power source goes out.

#### 4.1 Calculation of load power

In this discussion according to the power requirements of the Central Building (GP) of the University of PGRI Semarang in the amount of 26,120 Watts or hourly energy consumption of 26.12 KWh. This electricity load will turn on at 18.00 s / d 04.00, meaning that this electricity load will consume electricity for 10 hours. So the total energy consumed per day is 26.12 KW x 10 = 261.2 KW / day. So the total overall energy needed is 261.2 KWh.
4.2 Calculation of the Number of Solar Panels

From the calculation of the above energy consumption of 261.2 Kwh or equal to 261,200 Wh, we can choose the size of the solar panel that we need. In this design we use 500 Wp (Watt peak) solar panels, that is, this panel will produce a maximum of 500 Watts at 12 VDC per hour, so if these solar panels are installed a day (07.00-17.00 = 10 hours) assuming no cloudiness or intensity constant sunlight, this solar panel can produce 500 Wp x 10 hours of electricity = 5000 Wh or 5 KWh. The power output of a 500 Wp solar panel is produced at a temperature of 25 degrees Celsius, a pressure of 1.5 atm, with a light intensity of 1000 W / m2. In fact, on average 500 Wp solar panels will only produce an average electrical energy of around 600 Wh - 800 Wh in one day. This is because the intensity of sunlight is not the same throughout the day. In the design using 500 Wp solar panels, the following calculations are used:

\[
\frac{261,200}{500 \times 10} = 56 \text{ solar panels.}
\]

So the electricity produced is 56 units x 500 Wp = 28,000 Watts per one hour of heating at the peak of heating. In a day, more or less can produce electricity of 28,000 Wp x 10 hours Heating = 280,000 Wh.

4.3 Calculation of Battery Amount

For electrical energy storage systems 12 Volt batteries are used with a capacity of 200 Ah each. For battery needs, the calculation is carried out as follows:

Electric current per day is \[
\frac{261,200}{12 \times 10} = 2,177 \text{ Ampere}
\]

Number of batteries = \[
\frac{261,200}{12 \times 200 \text{ Ah}} = 110 \text{ batteries}
\]

Battery needs are considered to be able to serve every day without sunlight, so if we use a battery of 200 Ah 12 V, we need 110 batteries (200 x 12 x 110 = 264,000 watts).

4.4 Simulation Model

To see the results of the design of electrical resources using solar panels used a simulation model with a power simulator. In this simulation, it can be seen the accuracy of the number of solar panels and batteries on the electrical power produced.

![Figure 3 Design of solar panel simulations at the University of PGRI Semarang.](image)

In the design of figure 3 it consists of four solar panel units and a battery unit. Each solar panel unit consists of 14 solar panels and a battery unit consisting of an arrangement of 110 12V DC batteries.
To change the DC output voltage from a solar panel or from a battery to an AC voltage, a single phase inverter is used.

Figure 4. shows the output power at the load, which is 280,045 Watts. The size of the simulation output power is almost the same as the design output power of 280,000 Watts, so the calculation of solar panel capacity and battery capacity is correct.

Figure 5. shows the shape of the voltage at the inverter's load or output voltage. The sinusoidal output voltage is in accordance with the voltage used in the housing load. The load voltage amplitude is 220V AC.

5. Results and Discussion
In designing an off-grid solar panel system it is only used at night or when PLN electricity goes out. In the design in the Central Building (GP) four solar panels and a battery unit are needed. Each solar panel unit consists of 14 solar panels and a battery unit consisting of an array of 110 batteries. The simulation results show that the simulation output power is almost the same as the design output power, which is 280,045 Watts. This shows the results of the design can be used to make electricity resources using solar panels. The inverter's output voltage is also in accordance with the voltage used in the residential load, which is 220V AC.

6. Conclusion
In designing off-grid solar panel systems it is only used at night or when PLN electricity goes out. In the design in the Central Building (GP) four solar panels and a battery unit are needed. Each solar panel unit consists of 14 solar panels and a battery unit consisting of an array of 110 batteries. The simulation results show that the simulation output power is almost the same as the design output power, which is 280,045 Watts. This shows the results of the design can be used to make electricity resources using solar panels. The inverter's output voltage is also in accordance with the voltage used in the load of the house, which is 220V AC.

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