Solar Energy Hybrid Control System Design Photovoltaic Using Fuzzy Logic Controller

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Abstract. Design of hybrid control system of solar energy and State Electricity Company electrical energy using fuzzy logic controller aimed to set the time switch control with State Electricity Company electrical energy. The control system uses fuzzy logic to control when the dynamic load is supplied by the solar array and when supplied by a source of electricity. Input of fuzzy logic is the intensity of sunlight, the load current and the percentage of state of charge of the battery. The output of the fuzzy logic is a dynamic load of electricity supplied by the source. Switch on time is dependent on the three input. Results of experiments with the initial battery state of charge by 25%, switch control on at the time outside the peak load and can maintain the condition of the battery state of charge between 20-90%. Daily load changes of ± 20% does not affect the performance of the switch control (works well).

1. Introduction
The potential is a great alternative good for reducing people's dependence on source of electrical energy from State Electricity Company. Need efforts to reduce dependence on sources fossil energy which is getting depleted through diversification energy sources including the development of alternative energy that meets future energy requirements cheap, available in abundance, flexible inside use and friendly to the environment [1]. Photovoltaic Solar Energy is energy renewables that are easy to use and fast technological developments and the component production business The basics are the increasingly photovoltaic solar cells days are getting more affordable. The main drawback from photovoltaic solar energy is the electrical energy produced by solar cells greatly influenced by the intensity of sunlight accepted by the system, so it cannot be made the main source of electricity supply. Utilization of energy Maximum photovoltaic solar energy is indispensable with the system control hybridization between sources of electricity with State Electricity Company energy photovoltaic solar energy.

Some of the studies that have been conducted include by [2] regarding the optimization of hybrid systems (PV-gridconnected) with solar power sources as its main source and a source of diesel energy as a source reserve. As a result, a solar energy system is needed a lot of battery. Based on [3] on the design photovoltaic hybrid systems at substations require solar energy systems as many as 20 pieces with a capacity 175 Wp module. Meanwhile [4] about the design Hybrid solar power generation system with State Electricity Company electricity roads for home office energy systems solar as much as 30% of the total load. Referring to previous research, there are problems on the solar energy system that is needed very much so that there are still few who apply life daily. This is because it takes a lot of investment great at the start. Based on these problems, then In this research, a hybrid control system
will be designed photovoltaic solar energy with a power source State Electricity Company uses a fuzzy logic controller.

The purpose of this research is to design a hybrid system without any requirement for the number of solar energy systems needed, so that the investment is not expensive. The construction of a solar energy system can be done in an online manner gradually without considering the total load. Thing this can be achieved by turning photovoltaic solar energy into energy addition, is not the main energy.

**Literature review**

The hybrid system between the State Electricity Company electricity source and photovoltaic solar energy aims to get continuity supply electricity to the load. On this hybrid system consists of a photovoltaic array, a regulator (charge controller), batteries, and inverters. Direct current electricity from the module photovoltaic, will be converted into alternating current through the inverter. This hybrid system uses principles one-way work, that is, in a certain time load only supplied by one source of electrical energy. When the load is supplied by State Electricity Company electricity the connection to the photovoltaic solar energy is disconnected. So as otherwise, the electrical energy connection from State Electricity Company is cut off when the load is supplied by photovoltaic solar energy. This setting done automatically via a switch controller. Figure 1 depicts a hybrid system energy photovoltaic solar energy with the State Electricity Company network.

**Switch Controller**

Hybrid system control system between photovoltaic solar energy and energy State Electricity Company controller unit (switch controller). Hybrid system it uses the principle of one-way work, namely in at any given time the load is only supplied by one source / generator, the switch controller sets the source generator that will supply load [4]. Switch controller functions to control a hybrid system between photovoltaic solar energy and State Electricity Company energies. Load only supplied by one source at a time. On the switch the controller works automatically with detects the availability of photovoltaic solar energy sources, if energized photovoltaic solar energy is able to supply the load then the AC switch will off and the load is only supplied by photovoltaic solar energy. Condition conversely, if photovoltaic solar energy is not able to supply

*Figure 1. Switch controller*

Load then the AC switch will be on and the load is only supplied by State Electricity Company energy. When the hybrid system starts working, the unit switches the controller checks the solar sell voltage on the system photovoltaic solar energy. When the voltage is not greater than 11V (condition empty battery), then photovoltaic solar energy will charge (charging). Photovoltaic solar energy carries out the charging process (charging), the order is forwarded to State Electricity Company to supply load. If photovoltaic solar energy has done the charging process up to a voltage of 12V (full battery condition), then State Electricity Company will be off. This process occurs continuously.

**B. State of Charge Battery**

Battery state of charge is defined as the ratio of the total the energy capacity that can be used by a battery with full battery capacity. State of charge describes energy available and expressed as a percentage, sometimes considered a capacity value like capacity current. The nominal energy capacity of a battery is not can be issued in total, with our state of charge this battery can determine the total usable energy of A battery.

Suppose, a battery with 80% state of charge of capacity 500 Ah, the energy that can be used from a battery 400 Ah. Temperature and discharge rate can reduce the effective capacity of the battery [5].
written with the equation then the state of charge of the Battery is the comparison between the battery Ah max minus with Ah in + Ah out compared to Ah Max times with 100%. As shown in Eq 1 of the following:

\[
SOC = \frac{Ah_{max} - (Ah_{in} + Ah_{out})}{Ah_{max}} \times 100\%
\]

How to measure the state of charge of a battery can be done in 3 ways, namely:
1. Direct measurement, can be done if the battery can be charged at a constant value;
2. State of charge of the Specific Graphity measurement, this way subject to changes in measurement of weight active chemicals;
3. Estimation of state of charge based on voltage, carried out by measuring the battery cell voltage as a basis for calculating state of charge or remaining capacity.

The type of lead-acid battery that is widely used is type DM55-12. As for the data shett from this type of battery shown in Table 1 below:

**Fuzzy Logic Controller**

Fuzzy logic is emulating capabilities humans in thinking in the form of an algorithm then run by machine [6]. As for the fuzzy process This fiction is more or less depicted in Figure 2.

![Figure 2. Fuzzy logic controller](image)

Data that cannot be represented in a form binary. Fuzzy logic interprets statements that are vague into a logical sense. As for the points and stages in setting using This fuzzy logic and processing flow in rocessing data using Fuzzy Logic Controller shown in Figure 3. Figure 3 shows the development methodology system using Fuzzy Logic Controller. Fuzzy Logic Controller is a way to set multiple inputs so that the resulting output corresponding. When fuzzy logic is combined into a system, then the system modeling system as the main medium must be there first. The modeling of this system must be appropriate / defines the normalization of the post model used, meaning that the value that will be entered into the fuzzy must be

![Figure 3. Development using fuzzy controller](image)

If the antecedent part is more than one statement. The end result of this operation is degrees of truth antecedent in the form of a single number. Number this will be forwarded to the consequent section. Input Fuzzy operators are two or more degrees of membership of the input variables. The output is a value single truth.
2. Method
This research was conducted using a simulation model, the point is all the components of the system starting from energy source, energy storage / battery, load as well others are modeled using software modeling is then simulated to observe phenomena before and after application the system proposed in this study and at once conduct an analysis of the results of the observations.

System Block Diagram
Photovoltaic solar energy hybrid control system with energy State Electricity Company using fuzzy logic controller can be seen in Figure 4. Solar Array generates dc current low voltage while the grid has AC 220 voltage volt. The voltage from the solar array is voltage stabilized by the dc converter in order to charge the battery or into the input inverter. The inverter converts the voltage dc becomes the sinusoidal ac voltage to supply the load.

Designing Switch Controller Algorithm
Fuzzy Logic Controller Output from the switch controller with fuzzy logic the controller produces output in the form of switching on/off at the State Electricity Company energy source switch. Control this switch using artificial intelligence with the Fuzzy method Logic Controller which is affected by 3 inputs namely the state of charge battery, solar current (Isol) and load.

Fuzzy rules are designed based on “expert's experience ”, the expert experience of an operatorhumans in controller design to control the ON-Off process on a switch with a relationship hereinafter expressed by fuzzy rules. In The compilation of fuzzy rules uses types mamdani and there are several main steps, including:
1. Defining Fuzzy Input and Output Variables Controller
   In this research, the input variable includes state of charge Battery, Solar Current (Isol) and Load Current (iload). Meanwhile, the Fuzzy Logic Controller output is variable output that is manipulated and controlled so that produces ON / Off switching on the grid. From processing in fuzzy looks using the result of the process of dividing the universe using a "plotfis" function as shown in Figure 5.
2. Creating a Fuzzy Rule Base
   The fuzzy rule base is based on system characteristics which is controlled as can be seen in Fig 6. By looking at the opportunities and implications that exist then this hybrid control system can be controlled with using 75 (seventy five) possible ones happen.
3. Choose the defuzzyfikas method
   In the defuzzification process must pay attention aspects of continuity, situation disambiguity and plausibility, which means that defuzzification should produce a value which lies in the mid region [7]. As for This defuzzification method can be formulated with Equation 2.
   Where:
   \[
   COA = \frac{T_{tx} \times D_{x} \times T_{ty} \times D_{y}}{D_{x} \times D_{y}}
   \]
   COA = defuzzification result value;
   \(T_{tx}\) = mean x curve;
   \(T_{ty}\) = mean y curve;
   \(D_{x}\) = Membership degrees x;
   \(D_{y}\) = degree of membership y.

After creating the model, the simulation is run and see the results of switching on the grid with respect to 3 fuzzy input, especially when the battery is supplying the load peak. The above process is carried out continuously until obtained optimal results. Testing is carried out when solar irradiation conditions are different and load conditions which is different every hour within 1 day. The test is
carried out with a switch control controlled by Fuzzy Logic Controller [8]. The result analyzed to determine the effectiveness of the switch work control in optimizing solar energy generated.

Figure 4. Fuzzy logic controller

Solar Irradiation Pattern and Load

Data on solar irradiation patterns are usually expressed in units of calories, joules, or W / m². Solar irradiation data when the weather conditions are sunny in Patrang District Jember is used in this study as shown in Figure 7. While the pattern of daily load used is shown in Figure 8. The maximum load supplied by the system is 500 W which occurs during peak loads at 19.00-20.00 WIB. At that hour, the sun is gone it means that the load is supplied by the energy source State Electricity Company or source of battery energy that has been filled from the results of charging in the daytime [9].

Figure 5. Weather condition

Circuit Configuration and System Simulation Process Hybrid Control Photovoltaic solar energy hybrid control system design with State Electricity Company electricity source using fuzzy logic controller shown in Figure 9, which presents simulations performed. After system modeling [10] Formed, the program is run and analyzed the ON – Off results control to determine when the load is supplied to the source State Electricity Company and when will be supplied with photovoltaic solar energy.

3. Results and Discussion

In designing a hybrid control system, there are 2 a state when the photovoltaic solar energy source lacks energy (the load is greater than the energy produced) and excess energy (load is greater than energy resulting from). This lack of energy occurs when photovoltaic solar energy electrical energy is less than the load demand and the amount of energy deficiency in the load is the difference from photovoltaic solar energy electrical energy to the electrical energy demand load. Lack of energy demand occurs at 17.00 - 05.00. Whereas more energy occurs at photovoltaic solar energy 08.00-16.00 WIB. The amount of energy this will be
Figure 6. Design of the photovoltaic solar energy control system

Flowed on the battery to store energy so can be used during peak loads. The results of the design of the photovoltaic solar energy control system with a State Electricity Company electricity source using fuzzy logic. The controller was tested under several conditions, namely when PV module capacity is few, medium and many. Capacity the battery follows the capacity of the PV module to allow electrical energy generated can be stored by the battery.

**Less PV module capacity (3 PV modules)**

The hybrid control system aims to regulate switching the energy source of State Electricity Company ON so shortages this power can be covered by the system by looking at the conditions state of charge battery, load current demand and solar irradiation. In addition, to keep the battery condition on maximum and minimum ability limits in work, means that the state in the battery does not exceed 90% and minimum power of not less than 10%. Testing of the hybrid control system was carried out at this time the weather is sunny and the load is within 2 days simulation. The results showed solar irradiation for 1 day able to produce ± 612 Wh, meanwhile daily load of 4620 Wh. If compared with daily load, the power generated by energy photovoltaic solar energy is very small (about 13% of the total load). Hybrid control system test results, settings switch control ON most of the time. This is because of energy the electricity generated is very small.

**Low PV module capacity (12 PV modules)**

The solar panels used have the same power 50 Wp connected parallel as many as 12 panels(600 Wp power) to supply load demand daily amounting to 4620 Wh. ± energy generated
2nd International Conference Earth Science And Energy

IOP Publishing

IOP Conf. Series: Earth and Environmental Science 819 (2021) 012028
doi:10.1088/1755-1315/819/1/012028

Figure 7. Low PV module capacity (12 PV modules)

2448 Wh. If it is compared with the daily load, then the power generated by energy is very small (about 55% of the total load). Hybrid control system test results, settings switch control ON at 05: 00–07: 00 am due to battery state of charge still small. After that the switch control Off (the load is supplied by energy source) until 21:00 due to the energy stored by the battery is exhausted (below 10%).

C. Multiple PV module capacity (24 PV modules) The hybrid control system aims to regulate switching the energy source of State Electricity Company ON so shortages this power can be covered by the system by looking at the conditions state of charge battery, load current demand and solar irradiation.

In addition, to keep the battery condition on maximum and minimum ability limits in work, means that the state in the battery does not exceed 90% and minimum power of not less than 10%. The test is carried out for 2 days on which day first the initial condition for the state of charge of the battery is set at 25 % while on the 2nd day the state of charge condition of the battery is the remainder of the 2nd day. Solar anels used has a power of 50 Wp which is connected in parallel 24 panels (power 1200 Wp) to supply daily load demand of 4620 Wh. The simulation results show the power generated by, battery state of charge conditions and switch control settings ON based on the visible fuzzy logic controller in Figure 8. In Figure 8 is shown the switching time, solar power (Psol), load (Pload) and State Electricity Company (Pgrid) which affects the state of charge state of the battery. Switch control will ON effectively because it works when the system is not deep peak load state. With this switch control then we can keep the battery in order ideal conditions with state of charge between 20–90%.

Switch control using fuzzy logic the controller can still work properly at the moment daily load has increased by ± 20% of the previous load was 5489 Wh. The state of charge condition of the battery and switch control ON based on fuzzy logic controller which can be seen in Figure 15. Changes in daily load lead to working time switch control also changed. The state of charge of the battery remains in ideal conditions are in the range between 20–90%. state of charge battery shift caused by more power which is absorbed into the load, as a result the state of charge of the battery quickly drops and impacts the shift of the uptime of the switch control. Previous simulations shifted charging at 02.00 am at 01.00 am.

Figure 8. the switching time

4. Conclusion

The design of a hybrid control system between energies solar photovoltaic with a power source State Electricity Company can use this Fuzzy Logic Controller carried out that is complemented by a power supply setting using fuzzy logic with input in the form of state of charge battery, diesel current, and load current in the arrangement control algorithm. The amount of load energy is 4620 Wh and solar
panels vary by as much as 6, 12 and 24 panels arranged in parallel (each panel produces power 50 Wp). Batteries with a capacity of 100 Ah, 200 Ah and 400 Ah is used to store the resulting electrical energy conversion of solar panels during the day. Switch control using fuzzy logic the controller can still work properly at the moment normal daily load or during experience an increase of ± 20% from the previous load. Time work change control switch to keep battery state of charge stay in ideal conditions within range 20-90% due to more power absorbed into the load. The previous simulation was charging at 02.00 am shifted to 01.00 am.

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