

Design load controller and load shedding mechanism at DC house prototype

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Abstract. The DC house project is a pure DC electricity system to enable optimal use of renewable and alternative energy, DC House promotes a more sustainable solution by not using fossil-based fuels. DC sources are mainly from renewable generation, such as PV and wind turbines, the output from PV and Wind turbine produced is not stable, so there is a need for a regulatory system, arrangements can be made on the generation side and on the load side. Because the output of the generator is not constant, a setting on the load side is needed to adjust the generation capacity. If one of the offsets is to be released, a load shedding must be carried out to meet the load requirements. The release of the load is carried out when the supply is reduced because one of the generators is off, then the lower priority load will be released automatically. In this study simulated DC loads using PID control on the buck converter and load release using switching four loads with priority scale. The DC current sensor is used to determine the amount of current when determining the load released due to limited supply from the source.

1. Introduction

Indonesia is an archipelago located in a tropical region crossed by the equator, located between the continents of Asia and Australia and between the Pacific and Indian oceans, with such a geographical location that allows our country to have a large renewable energy potential (Renewable Energy). Utilization of Renewable Energy is still not maximized, especially solar energy and wind energy with 17.02 MW installed solar energy and 1.12 MW Wind energy since 60,789.98 installed generating capacity in Indonesia [1]. Hybrid Power Generation is the use of two or more power plants that use different energy sources by combining the two power plants so that they can utilize the power plants together and produce a reliable and efficient energy supply. One hybrid generation that has a long-term prospect is a hybrid generator with renewable energy sources from solar and wind energy sources. One of the main weaknesses of renewable energy sources is that energy continuity depends on cycles and climatic conditions. For example the use of solar panels that can only utilize solar energy during the day. However, this problem can be overcome by using DC electricity, which will integrate several renewable energy sources, batteries and DC loads, all into one DC Home system [2,3].

DC House Load (DC House) needs to be done to control the load and release of the load, control directly and indirectly can be used if there is a change in the load, especially the load increase to keep the voltage stable. One control method can use the PID. The PID controller can be designed using the MATLAB function to produce a set of coefficients related to the controller characteristics and implemented in a microcontroller. To ensure a constant output voltage, the classic linear design of the



control is often used [4]. The release of the load can be done by using a relay-based load, priority when there is a reduction in energy supply from renewable energy.

2. Buck converter

The dynamic equation of the converter is written with the assumption that the switch is a linear element [5]. The step-down DC-DC converter, commonly known as a buck converter [6,7]. The power buck converter is the most widely used DC-DC converter topology [8]. DC-DC converters are electronic devices that are used whenever we want to change DC electrical power efficiently from one voltage level to another. In the previous chapter, we mentioned the drawbacks of doing this with a linear regulator [8], by using a buck converter, the supply voltage to the DC House is relatively stable, according to the load voltage that is 12 V like the buck converter image as shown in figure 2. So that the output voltage can be made stable according to the desired load voltage setting, one can control it. PID control, PID control is called Proportional, Integral, Derivative [9].

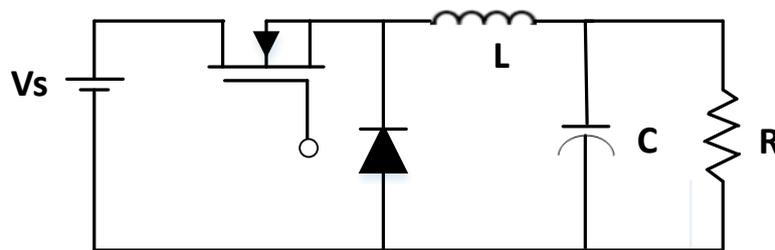


Figure 1. Buck converter.

Buck converter transfer function [2]:

$$H(s) = V_s \frac{1}{\left(1 + s \frac{L}{R} + s^2 LC\right)}$$

3. Model PID controller

The control method that gives the best performances under any conditions is always in demand. Conventionally, the DC/DC power buck converters have been controlled by linear voltage modes and current mode control methods such as proportional-integral (PI) and proportional integral derivative (PID) controller. The proportional constant K_p is implemented digitally by a constant gain. Since a digital computer or processor has finite word length, the constraint cannot be realized with infinite resolution. The numerical integration technique i.e. the trapezoidal rule of integration can be used to digitally approximate the integral controller K_i/s . The time derivative can be approximated by a backward difference rule [10]. A PID controller is a feedback loop controlling mechanism. A PID controller corrects the error between a measured process value and the desired set point by calculating and then a corrective action to adjust the process as per the requirement [11]. PID controller has faster response and smaller overshoots under the load change condition [12-14]. Dusan Gleich et al explained a digital controlled buck converter with different control algorithms [15]. Analog converters were first designed using frequency response techniques and converted into digital controllers [16].

4. System design

Controlling the load voltage so that it is stable is done using a buck converter using the PID control, the PID control used is taken from MATLAB. The source of the Wind Turbine that has been changed to DC and PV voltage is assumed to supply a controlled battery, then supply the voltage to the buck converter with an input of 24 volts, the buck converter output is planned to be 15 volts DC with a 12 V DC house load due to a voltage drop on the conductor of converter to load [17]. DC house load is simulated using 4 load resistors with a load release scenario as follows:

4.1. Scenario I (normal conditions)

The load is supplied from Renewable energy (PV and Wind Turbine) and batteries with an electric source capacity greater than the load so that the conditions are in normal conditions with a load of 10 A.

4.2. Scenario II (one of the dead sources is Wind Turbine off)

The load supplies from renewable energy only, so the burden must be released with the lowest priority (load 4 of 2A).

4.3. Scenario III (one of the dead sources, namely Renewable Energy PV off)

The load is supplied from the battery and the Wind Turbine only so that the load must be released with loads 3 and 4 removed.

4.4. Scenario IV Load is supplied from Batteries only with WT and PV off, load 4,3,2 while a live load is loaded 1 as the top priority.

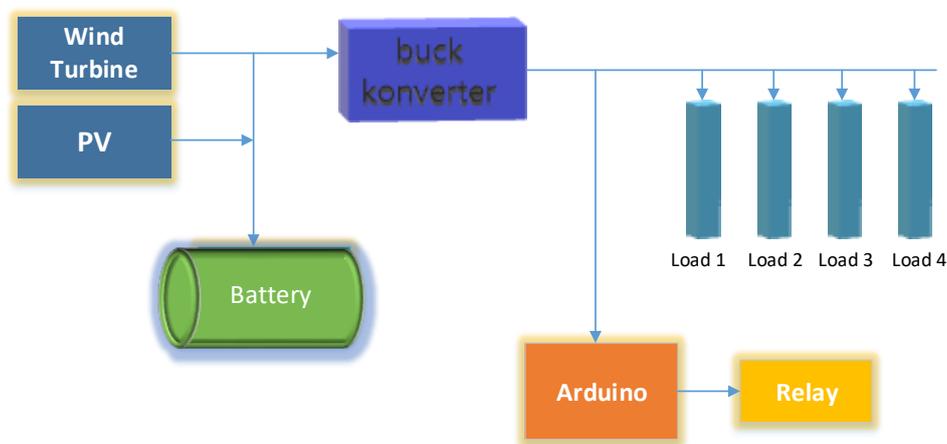


Figure 2. Block diagram of load controller design and load shedding mechanism of the DC house prototype.

5. Load controller planning using buck converter

Specified Parameters	: $V_{in} = 24\text{ V}$
	; $V_{out} = 15\text{ V}$
Switching Frequency	; $f_s = 100\text{ kHz}$ then $T_s = \frac{1}{f_s}$
Full load current	; $I_{omax} = 10\text{ A}$
	; % Min-Load ccm = 10%
Output $V_{pp-ripple}$; $\Delta V_o = 10 \cdot 10^{-3}\text{ V}$

5.1. Determination of inductance value

A more practical approach is to size the critical inductance by using percent peak to peak inductor current ripple Δi_L based on the maximum load current (calculated at maximum output power) [18]. The magnitude of the inductance and capacitance in the buck converter can be calculated by equation:

$$\text{Determination} \quad ; L_c = \frac{V_i - V_o}{2I_{omin}} t_{on} \quad \text{or} \quad L_c = \frac{(1-D)}{2I_{oc}} t_{on}$$

$$\text{Equivalent Series Resistance} \quad ; ESR = \frac{\Delta V_o}{\Delta I_L}$$

$$\text{Determine the value of the capacitor} \quad ; C_0 = \frac{(1-D)}{8 \cdot L \cdot f^2} \times \frac{1}{\%V_o}$$

Inductance value is selected $L = 3,1 \times 10^{-5}\text{ H}$ and $C = 150 \times 10^{-6}\text{ F}$

6. Planning of load shedding mechanism at DC house

DC House consists of several components, namely energy sources, MISO DC-DC Converter [19], distribution, batteries, and loads. The distribution system allows DC electricity to be used directly in homes [20]. DC house load is simulated using 4 load resistors. The workload release is when the current reads using the current sensor exceeds the specified reference current, Arduino will give the command to open the lid switch, opening the load switch using a relay in accordance with the load release scenario which has been made. Release of sources from Wind Turbines, PV and batteries are done manually.

- Load No.1. main priority : V= 12 volt, R= 4 ohm : P = 36 W; 3A
- Load No.2. main priority : V= 12 volt, R= 4 ohm : P = 36 W; 3A
- Load No.3. non priority : V= 12 volt, R= 6 ohm : P = 24 W; 2A
- Load No.4. non priority : V= 12 volt, R= 6 ohm : P = 24 W; 2A

7. Result and discussion

From the results of the design above, a simulation using Simulink using a 24 V DC supply represents the input from a renewable source and a battery of 24 volts, and an output of 15 volts DC with the circuit shown in Figure 3 below:

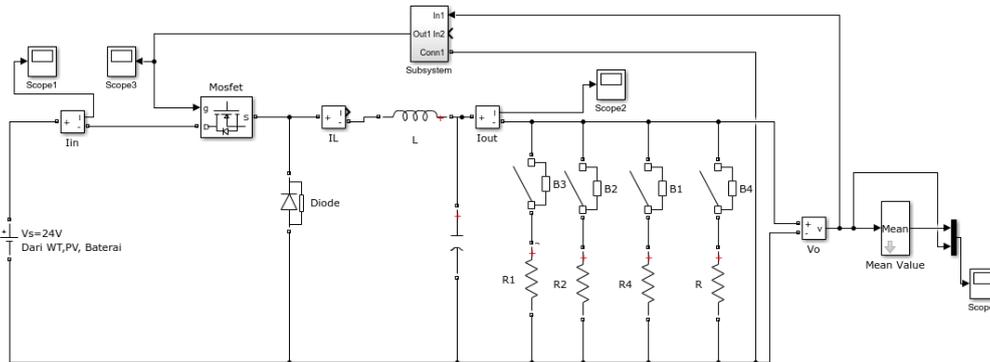


Figure 3. Simulink buck converter simulation with PID using 4 loads.

The simulation is carried out using four loads, from the simulation results with total load the following results are obtained:

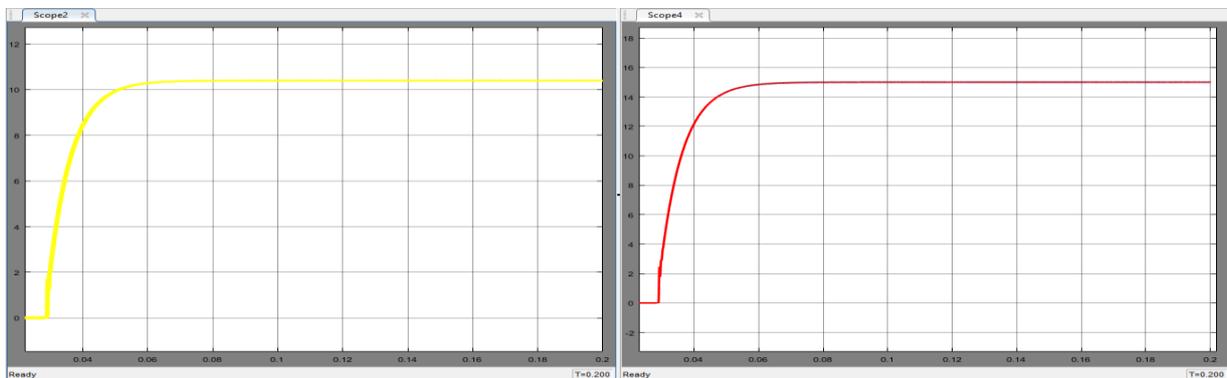


Figure 4. Scope output voltage and load current with full load.

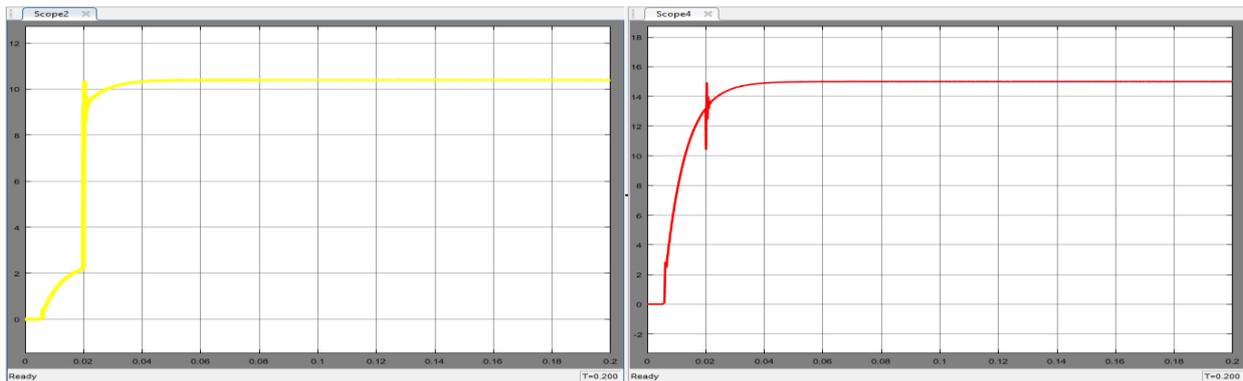


Figure 5. Scope output voltage and load current with release at one load.

The output voltage when loaded with 4 loads is shown in Figure 4 (a), the simulation results show that the output voltage waveform is constant 15 volts after 0.04 s, and the current wave shown in Figure 5 is 10 amperes or 120 watts. When the load is released 4,3,s2 (b) the output voltage waveform is still stable at 15 volts and there is no significant change compared to when loaded with a full load while the magnitude of the current becomes 3 amperes because only priority load 1 is alive.

8. Conclusion

From the results of simulations that have been carried out in Simulink, it can be concluded that when there is a release at one load, the buck converter output voltage remains stable at 15v after 0.04 seconds as well as the current, remains stable at 10 A after 0.04 seconds. So the planned buck converter can be used to supply DC homes.

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