Design of Full-Bridge Rectifier for Underwater Remotely Operated Power Supply Unit

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Abstract Rectifiers or AC/DC converters are widely used in industrial applications. Input AC voltage is rectified into DC voltage and smoothen using the filtering circuit which consists of electrolytic capacitors. The 220VAC, 50 Hz input voltage source is increased and converted to get 400VDC by using a step-up transformer and full-wave bridge. The 620 μF filtering capacitor is chosen based on the calculation and simulation. This paper described the step to design rectifier and proposes the component configurations by which voltage drop and ripple voltage can be reduced. The results of respective simulations are shown through Proteus software program and their parameters are calculated.

Keywords Rectifier · Full-bridge · ROV · AC/DC converter

1 Introduction

Rapid developments in the marine operations field and activities have demanded the growth of underwater vehicle called Remotely Operated Vehicles (ROV). The automation of such vehicle requires sufficient power sources capacity to make all components build inside the ROV are working as expected. The power transmission is completed through tether cable along with communicating systems. The longer the cable is needed to transfer the power to the ROV to the deeper area of the ocean.

The AC/DC voltage converter for the ROV power supply unit (PSU) is designed using a conventional full bridge rectifier with a filter capacitor. In the first stage, the single-phase power source, 220 VAC with frequency 50 Hz is increased into 400 VAC using a step-up transformer. Later the 400 VAC is then converted into 400 VDC using full-bridge rectifier and a smoothing capacitor. Then the supply is transmitted through the 100 m long umbilical cable. The design of the rectifier is based on the power requirements from the thrusters and other electronics part in the

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ROV. The primary constraint with regards to the power system is the space available for DC to DC power conversion on board. The required voltage at the output of the rectifier must compensate the transmission losses in addition to the voltage required by the ROV's load.

The smoothing capacitor value is achieved by calculation and simulation iteration. The simulation of the rectifier is done by using Proteus software. The suitable capacitor value is chosen based on the comparison with ripple voltage.

2 Design of Single-Phase Full Bridge Rectifier

The primary function of the PSU was to convert 220 VAC mains into 400 VDC and supply it at a rate of 5A to the ROV. Based on Roger et al., the most safest and reliable ways to provide an isolated or ungrounded DC supply is by using toroidal transformer with double windings to step-up the mains supply voltage before rectifying it [1]. This is because the toroidal transfer would provide complete isolation between the inputs and outputs. Besides, the double windings would provide greater reliability than single wounded-auto-transformers.

The circuit topology for the conventional full bridge rectifier with filter capacitor is shown in Fig. 1.

Some equations and calculations are done in order to finalize the design [2, 3].

i. Input voltage to the step-up transformer
   Input voltage the using single-phase 220 VAC mains with 50 Hz frequency

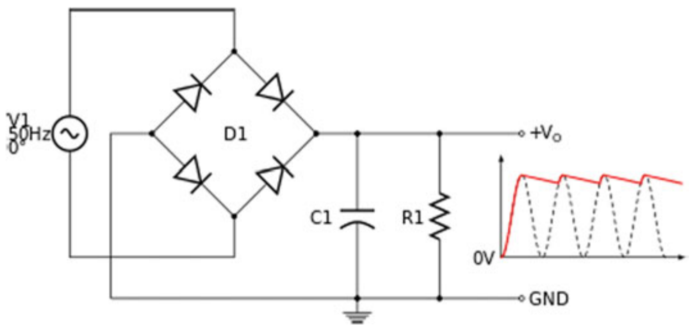

Fig. 1 Full-bridge rectifier with filter capacitor

ii. Transformer primary and secondary windings

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \quad (1)$$

where

V_s secondary voltage
V_p primary voltage
N_s secondary winding
N_p primary winding

$$N_s = \frac{400\ \text{V}}{220\ \text{V}} \times 1 = 1.82 \approx \mathbf{2}$$

iii. Output voltage of the rectifier

$$\text{Output voltage} = \sqrt{2} \times \text{Input voltage}$$
$$\text{Output voltage} = \sqrt{2} \times 400\text{V} = \mathbf{565.69\ V} \quad (2)$$

iv. Peak diode current

$$\text{I}_\text{m} = \frac{\text{Vm}}{\text{R}} \quad (3)$$

$$\text{I}_\text{m} = \frac{400\ \text{V}}{100} = \mathbf{4\ A} \quad (4)$$

v. Load resistor = **100 Ω**

2.1 Simulation of Rectifier

The simulation was carried out using Proteus software as shown in Fig. 2 in order to find the suitable capacitor value. The result of simulations is shown in figures below. The smoothing capacitor converts the full-wave rippled output of the rectifier into a smoother DC output voltage.

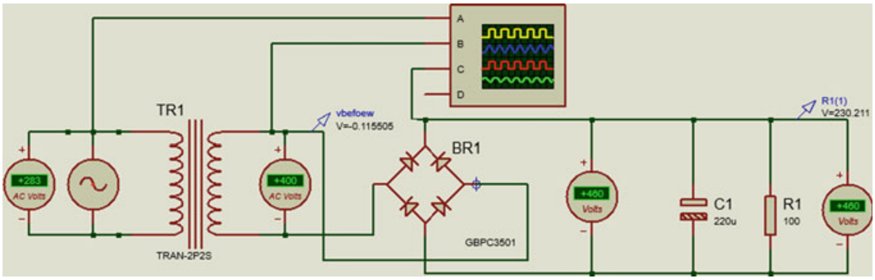

Fig. 2 Circuit configuration on Proteus software

2.2 Filtering or Smoothing Capacitor

Figure 3 shows the waveform of the result of using a 220 μF across the rectifier output. This results in the capacitor discharging down to about 283.1 V − 208.6 V = 74.5 V. The capacitor maintains the voltage across the load resistor until the capacitor recharges once again on the next positive slope of the DC pulse. Thus, the DC voltage applied to the load resistor in higher voltage drops. This can be improved by increasing the value of the smoothing capacitor [4–7]. The ripple voltage is done by using Eq. 5 [4]:

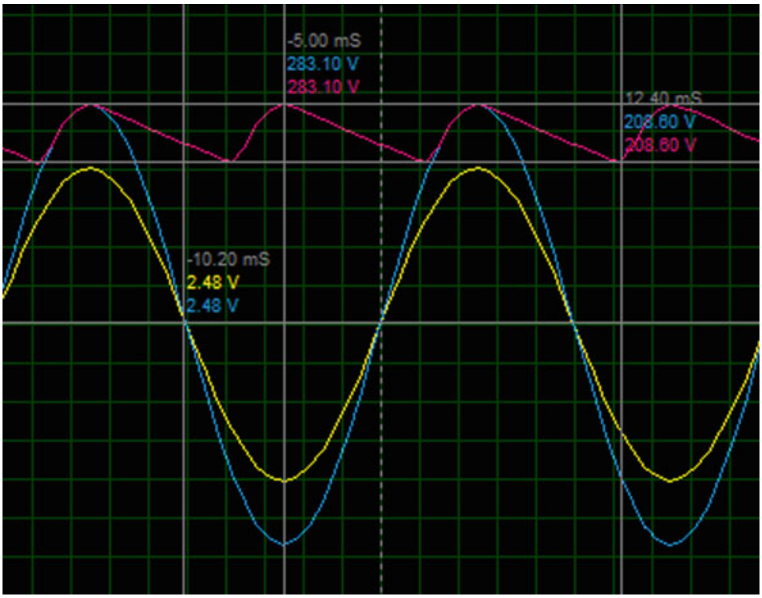

Fig. 3 Waveform of rectifier by using 220 μF

$$V_{ripple} = \frac{I_{load}}{f \times C} \tag{5}$$

where f is twice that of the AC supply frequency.

Simulations are conducted in iteration in order to get the suitable capacitor value. Table 1 shows the result of ripple voltage with different capacitor value.

It is seen from the above table that the value of voltage drops and ripple voltage for the rectifier is decreasing with the increasing value of capacitor. Changing the capacitor is not the deciding factor of a good rectifier, so it can be concluded that by using 620 µF with reduce the voltage drop and ripple voltage. The voltage waveform is shown in Fig. 4.

Table 1 Smoothing capacitor simulation and calculation

Capacitor value (µF)	Voltage drop	Ripple voltage (V)
220	283.1 V − 208.6 V = 74.5 V	227.27
320	283.1 V − 225.9 V = 57.2 V	156.25
420	283.1 V − 238.4 V = 44.7 V	119.05
520	283.1 V − 245.9 V = 37.2 V	96.15
620	283.1 V − 258.3 V = 24.8 V	80.65

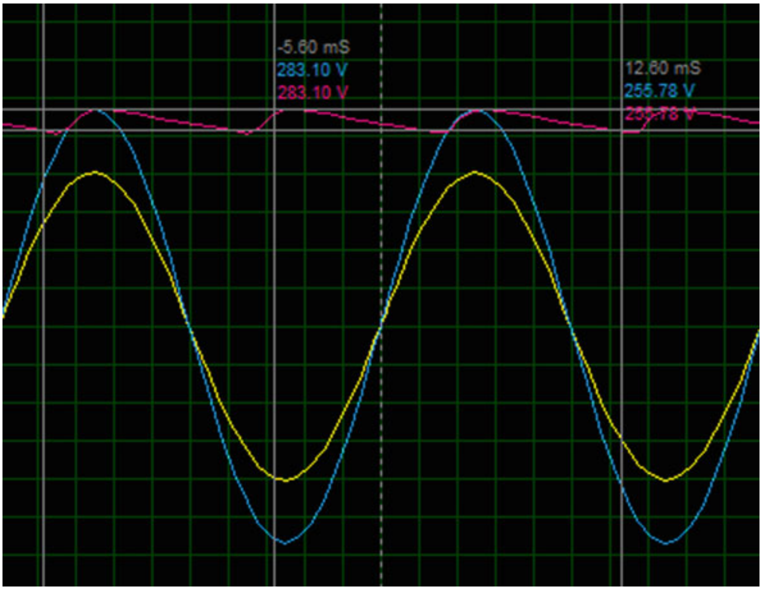

Fig. 4 Waveform of rectifier by using 620 µF

3 Conclusions

From the above design and simulation, step-up transformer is used to increase the input AC voltage source. Then, the voltage source is converter into DC voltage source by using full-bridge rectifier. The 620 μF smoothing capacitor is chosen to reduce the ripple voltage. The circuit topologies can be used for low and high voltage applications.

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