International Journal of Power Electronics and Drive Systems (IJPEDS)
Vol. 14, No. 3, September 2023, pp. 1368~1373
ISSN: 2088-8694, DOI: 10.11591/ijpeds.v14.i3.pp1368-1373

Performance investigation of bridge-less power factor correction circuit with MOSFET

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Article Info

Article history:

Received Aug 25, 2022
Revised Mar 20, 2023
Accepted Mar 31, 2023

Keywords:

Bridge-less
MOSFET
PFC
Total harmonic distortion

ABSTRACT

The aim of this paper is to study and investigate the performance of power factor correction (PFC) circuit implemented with the semi bridge-less configuration. The transistor-diode module APT50N60JCCU2 has been used in the proposed circuit and the UCC28070 controller has been used as a controlling device for the power factor correction (PFC) circuit. Testing has been performed in two steps. In the first step, the test was conducted on (230 Vac), while in the second step, the test was conducted on (115 Vac) as alternating input voltages. The testing results of both voltages were compared and analyzed in terms of efficiency, power factor, total harmonic distortion (THD) in order to determine the efficiency of the power factor correction circuit. The results obtained indicate that this circuit has efficiency up to 97% and a power factor close to 0.91 with the input voltage of 230 V.

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1. INTRODUCTION

In practice, the controlled power converter behaves as a resistive load on the power grid, which improves energy quality and overall efficiency and helps meet IEC1000-3-2 harmonization standards [1]. The introduction of the controlled power converter will encourage better use of the grid by avoiding the harmonic components through the energy system [2]. As a result, energy loss is reduced and energy quality is improved. However, improving energy quality by using controlled power converters to reduce not only PF but also THDi, distributors and generators [3]. However, this topology has the following comparative disadvantages in medium-power applications: i) This topology has the following properties; ii) BBC has less than three semiconductor devices in its current path and transmission losses increase; iii) BBC IEC 1000-3-2 requires a TDi frequency greater than 30 kHz; and iv) the inductor is on the DC side, which requires design considerations to avoid the saturation [4]–[7].

A boost rectifier with zero-voltage switch (ZVS) pulse-width modulation (PWM) is used in [8]. In this rectifier all semiconductor devices are soft-switched and the main switch is used to reduce voltage and current. This will increase the efficiency and improves power factor, but requires additional circuitry for zero voltage switching and a hall effect sensor to detect the input current signal. The constant conductance boost converter is simple and capable of handling high power. So, this is used for the power factor correction (PFC) circuit. But high output voltage and current cause serious reverse recovery problem [9].

A bridge rectifier with diode recovery problem is presented for PFC as shown in [10]. An inductor with two diodes in the circuit reduces the difficulty of fixing the two devices and reduces the loss of the input, but it creates a large filter with the transformer thus making the current transition sensitive. A similar half-bridge electronic circuit was developed for fluorescent lighting as explained in [11]. It has an advanced PFC and a half-bridge converter. Transmission loss is reduced in this topology.

Two methods of reducing input noise in non-PFC converters are studied in [12]. The first method is based on PFC modification. In the second method we developed a normalization method to reduce the normal noise. For continuous conduction mode (CCM) and (discontinuous conduction mode) DCM, the performance improvement of bridgeless PFC conversion is done in [13]. The disadvantages of advanced PFC are that the DC voltage is higher than the maximum voltage, there is no difference between the input and output voltage, the starting current is large, there are no restrictions under stress conditions [14].

In terms of its application, CBP converters are widely used in modern power converter suppliers for telecommunications equipment, and electric vehicle chargers [15]–[18]. High power factor and high efficiency are the characteristics of this technology [19]. In recent years, buck–boost converter (BBC) topologies have been combined with an increase in DC load due to their general simplicity [20].

However, this converter shows a significant amount of normal mode noise in the input current, which requires additional components that increase the complexity of the circuit. The common mode problem is caused by floating, which pulsates according to the switching frequency [21]. In addition, this topology requires an additional inductor that increases the weight, size, and cost of the power converter [22].

However, this converter has typical input noise and requires additional components. The problem with the conventional approach is caused by the floating output ground [21]. Furthermore, it requires one inductor, which causes more weight, size of the converter [22]. In this paper, a rectifier with a power factor correction implemented with two field effect transistors (FET) for power output greater than 3 KW with various input voltage has been studied. The efficiency, power factor, THD of the proposed PFC were investigated.

2. METHOD

Figure 1 shows the proposed bridge-less rectifier for power factor output correction of more than 3 KW. In this configuration, the PFC coil is divided into two smaller windings and connected directly to the AC input. Also, two diodes (Da and Db) are connected to the PFC output ground, so that the input voltage no longer floats relative to ground. In this way, the PFC input voltage is corrected for sinusoid relative to ground, thus eliminating the problem of voltage measurement. Also, the placement of diodes reduces noise [23].

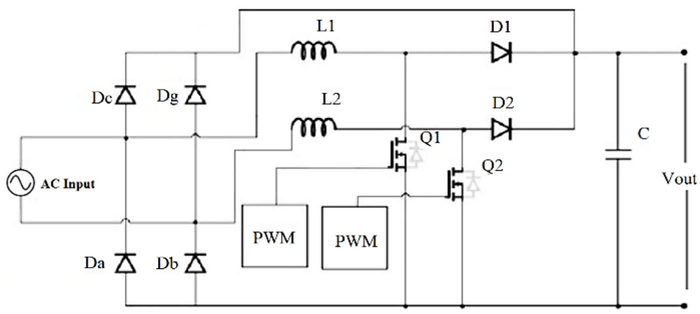

Figure 1. PFC with bridge-less rectifier [23]

The main task of PFC is the increasing of active power obtained from the network and reducing the higher harmonics of the current retransmitted to the network. Power factor (PF) is defined as the ratio of active power (P) to apparent power (S) and can have a value between zero and one, it can be calculated by (1) [24]:

$$PF = \frac{P_{out}}{P_{in}} = \frac{P(W)}{S(VA)} \tag{1}$$

To maintain the simplicity of the power factor correction rectifier, the Texas Instrument Steering Wheel UCC28070 is used. This circuit provides two phase control signals (PWM) shifted by 180°, allowing it to control interconnected PFCs. Figure 2 shows a simple scheme of PFC with control circuit UCC28070 [24].

In order to simplify the scheme, reduce losses and reduce electromagnetic interference, instead of separate transistors and diodes, two transistor-diode modules APT50N60JCCU2 were used, with the following characteristics: VDSS = 600 V, ID = 50 A. These modules are used to control AC and DC motors, in switching power supplies and power factor correction rectifiers.

The transistor used in the module is a MOSFET CoolMos with an extremely low RDSon = 45 mΩ. The diode is a SiC Schottky diode. The packaging is SOT-227. The advantages of this module are exceptional characteristics when working at high frequencies, stable behavior at different temperatures, the possibility of direct mounting on the cooler. In the control circuit UCC28070, a current transformer is used between the drain transistor and the anode of the diode. Using this module, this is not possible, because the drain of the transistor and the anode of the diode are at the same point. This is why a current transformer is placed between the transistor source and ground. The installation of the current transformer in the case of using the module is shown in Figure 3.

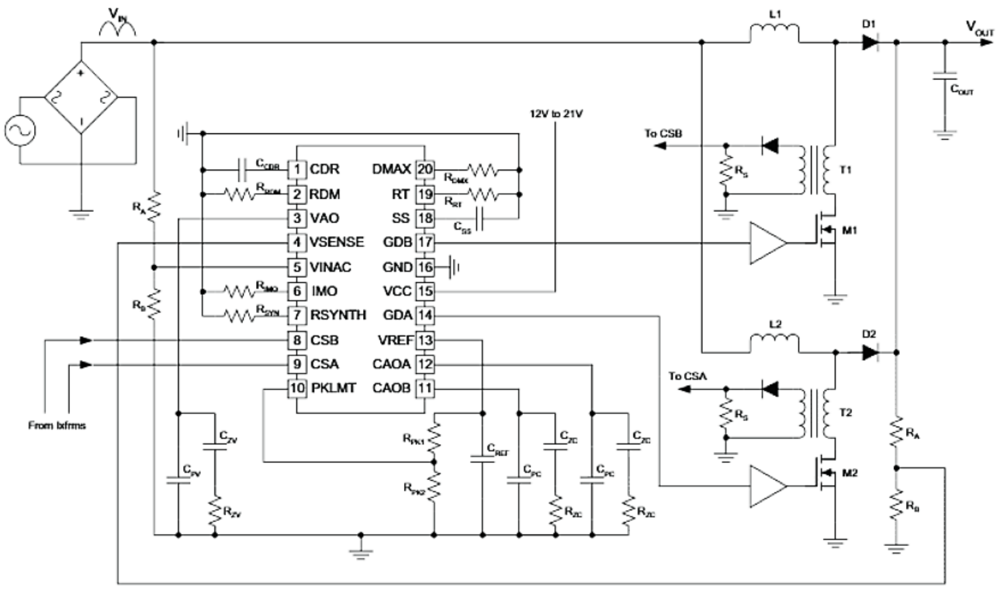

Figure 2. Simple scheme of PFC with control circuit UCC28070 [24]

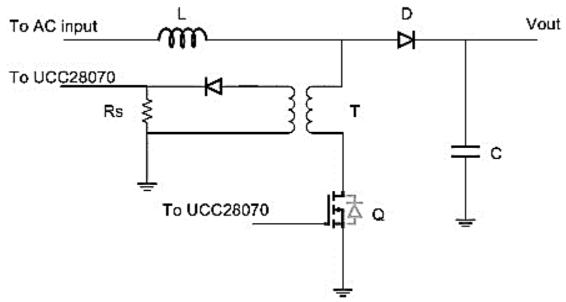

Figure 3. Setting up the current transformer by using the transistor diode module [25]

Since one of the main goals is to maximize the efficiency of the rectifier, a bridge-less configuration is used. This will increase the efficiency by reducing the number of switching elements. The transistor-diode module APT50N60JCCU2 is used [26]. This PFC is tested at input voltages of 230 Vac and 115 Vac, checking efficiency, power factor.

3. RESULTS AND DISCUSSION

The bridge-less PFC was tested with the UCC28070 control circuit. During the test, the power factor (PF), efficiency (Pout/Pin) are checked. The test is carried out under the following conditions, input voltage: 230 Vac and 115 Vac, PFC output voltage: 330 Vdc, PFC operating frequency per module: 147 kHz, maximum power: 4150 W at 230 Vac input and 2200 W at 115 Vac input.

The maximum power at the PFC output depends on the reverse gain current. In this case, the tested PFC is adjusted by selecting the resistor Rs from the PFC control circuit (for lower resistor values, more power is obtained). Table 1 shows the power factor (PFC) and the efficiency for the input voltage of 230 Vas, Rs = 5 Ω and at different input powers. Figure 4 illustrates the power factor graph for input voltage of 230 Vas and input voltage of 115 Vas at different inputs. Table 2 shows the power factor and the efficiency for the input voltage of 115 V, Rs = 10 Ω at different input powers.

Figure 5 illustrates the efficiency graph for input voltage of 115 V, Rs = 10 Ω at different input powers. The next parameter to be tested is the higher harmonic content. The results are given in Table 3. Figure 6 illustrates the total harmonic distortion (THD) for the input voltage of 230 Vac and input voltage of 115 Vac. From Table 3 and Figure 5 we can see that the THD has higher levels in the case of low output power (2 KW), while it is lower levels in the higher output power (< 2 KW).

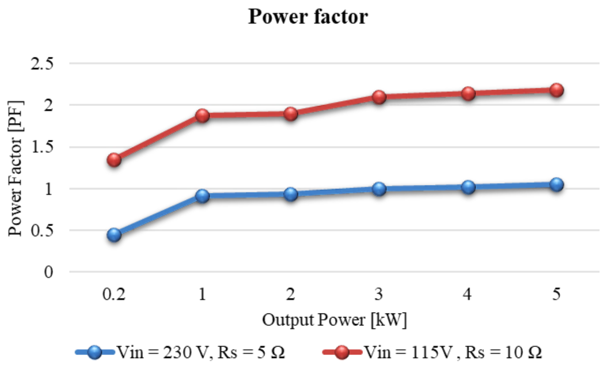

Figure 4. Power factor graph representation for the input voltages of 230 Vac, and 115 Vac

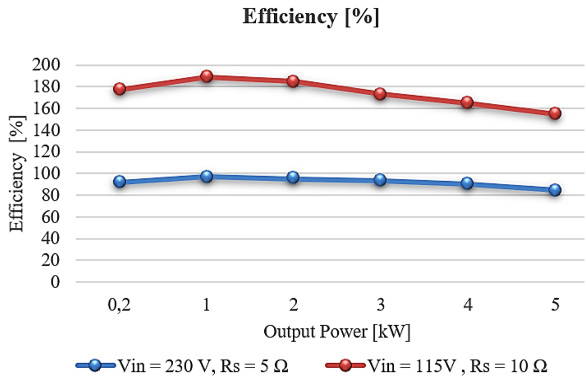

Figure 5. Efficiency graph representation of the input voltages of 230 Vac, and 115 Vac

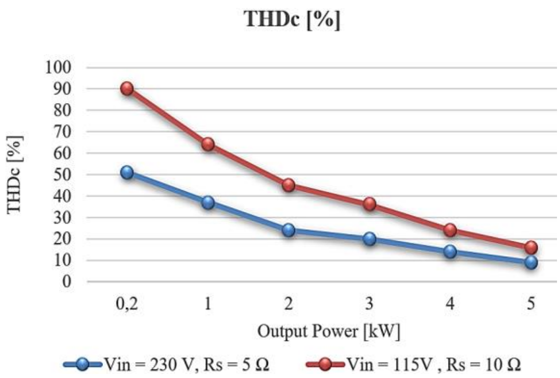

Figure 6. THD graph representation for the input voltage of 230 Vas, Rs = 5 Ω and for input voltage of 115Vac, Rs = 10 Ω

Table 1. Power factor and the efficiency for input voltage of 230 V, at different input powers

Parameter	Measurements				
Input power [KW]	0.09	0.9	1.49	2.35	4.5
Output power [KW]	0.08	0.78	1.35	2.29	4.1
PF	0.88	0.91	0.95	0.84	0.98
Efficiency [%]	93	95	97	96	94

Table 2. Power factor and the efficiency for input voltage of 115 V, Rs = 10 Ω at different inputs

Parameter	Measurements				
Input power [KW]	0.094	0.54	0.98	1.42	2.41
Output power [KW]	0.082	0.57	9.12	1.05	2.11
PF	0.87	0.95	0.97	0.95	0.98
Efficiency [%]	84	91	94	99	87

Table 3. Total harmonic distortion (THD) for input voltage of 230 Vac, Rs= 5 Ω, and 115 Vac, Rs=10 Ω

Vin = 230 V, Rs = 5Ω			Vin = 115 V, Rs = 10 Ω		
Input power [KW]	Output power [KW]	THDc [%]	Input power [KW]	Output power [KW]	THDc [%]
0.087	0.081	51	0.91	0.82	39
0.45	0.43	37	0.81	0.51	27
1.03	1	24	0.96	0.92	21
1.52	1.42	20	1.21	1.02	16
2.3	2.2	14	1.77	1.52	10
4.3	4	9	2.51	2.21	7

4. CONCLUSION

This paper presents a rectifier with a power factor correction for power output greater than 3 KW. Different structures of the PFC rectifier are described, in which a half-bridge construction was used for the realization of this circuit, which contains a bridge rectifier, but uses only two of these rectifying diodes. The rectifier efficiency, power factor, THD are checked. This structure is used to achieve maximum efficiency and as well as maximum power factor. The results showed that for PFC 3 KW the efficiency was higher than 92% at all power, while the highest efficiency was 97% at power from 1 to 2 KW. Efficiencies above 3 KW begin to decline. The reason is the higher output current (with the square of the current, the losses in the components increase). Efficiency up to 3 KW is above 95%. The power factor is above 0.9 at all powers greater than 700 W. This is the value obtained at an input voltage of 230 Vac. At the input voltage of 115 Vac, efficiency decreases, but power factor increases, as evidenced by the results shown for a maximum output power of 2,200 W.

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