DESIGN OF BACK TO BACK CONVERTER FOR SMALL HYDRO POWER PLANT

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Abstract: Renewable energy sources are important in recent years. Small hydro power plants are one of them which does not devastates the country, and which has relatively stable operation. However, in summer time with low river flow, they operate with low power and they have low efficiency. This paper demonstrates method to decrease the losses by back to back converter. Design of the converter is described, and fabricated part of the converter is depicted.

Keywords: Small hydro power plant, Induction machine, Efficiency, Back to back converter

1 INTRODUCTION

With the development of technology and living standards, people are beginning to think not only about their standard of living, but also about the impact of their actions on the environment. We can say that this is important because there are more and more pollution problems [1]–[3]. Various green technologies [4] a renewable energy sources [5] are emerging in response to these problems.

Small hydropower plants are one of the possible types of renewable resources [6]. They can be run on small watercourses without large buildings that would surround the environment, as opposed to wind farms or photovoltaic power plants, which we can say are ugly. Small hydropower plants can be built in many configurations [7], however, the most common is the use of an asynchronous generator.

The asynchronous generator is suitable due to its easy connection to the network and mainly because it is not necessary to control it during operation. However, this advantage is offset by the disadvantage of high losses at low power. In fact, at a constant voltage and frequency, the idle generator is approximately constant [8]. Thus, with a reduction in performance, the relative size of the losses increases, and the efficiency decreases.

Generally, an asynchronous generator is optimized to operate at rated power, but at lower power, the efficiency of the generator can be optimized. This optimization is the goal of the present work and it should bring an increase in efficiency in the mode of generation of lower power than rated power.

2 OPTIMIZATION PROCES OF SMALL HYDRO POWER PLANT OPERATION

Small hydro power plants are sensitive to changing river flow, so they very often work at lower power than nominal [6]. It causes operation with low efficiency, due to constant no load losses [9]. Average power per one month of typical small hydro power plant [9] is depicted in Figure 1:. It is clear that power oscillates during the year. During the summer, the power is near to zero. In rest of the year is the power sometimes near the nominal power 15 kW and sometimes is lower. It is better demonstrated in Figure 2:, where the average power is depicted relatively for five years. One third of time, the power is near zero. One quarter the power is higher than 7 kW. Rest of time the power

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is between one and seven kilowatts, where the efficiency could be improved by reducing the losses in induction generator and in hydro turbine.

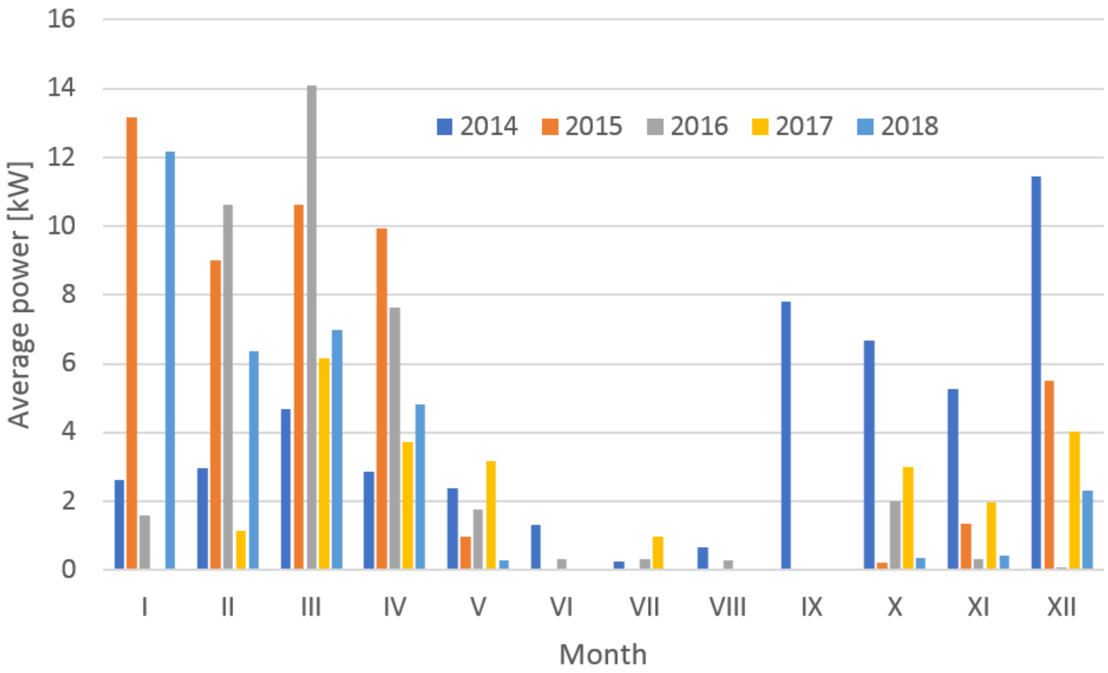

Figure 1: Average power in each month for the last five years

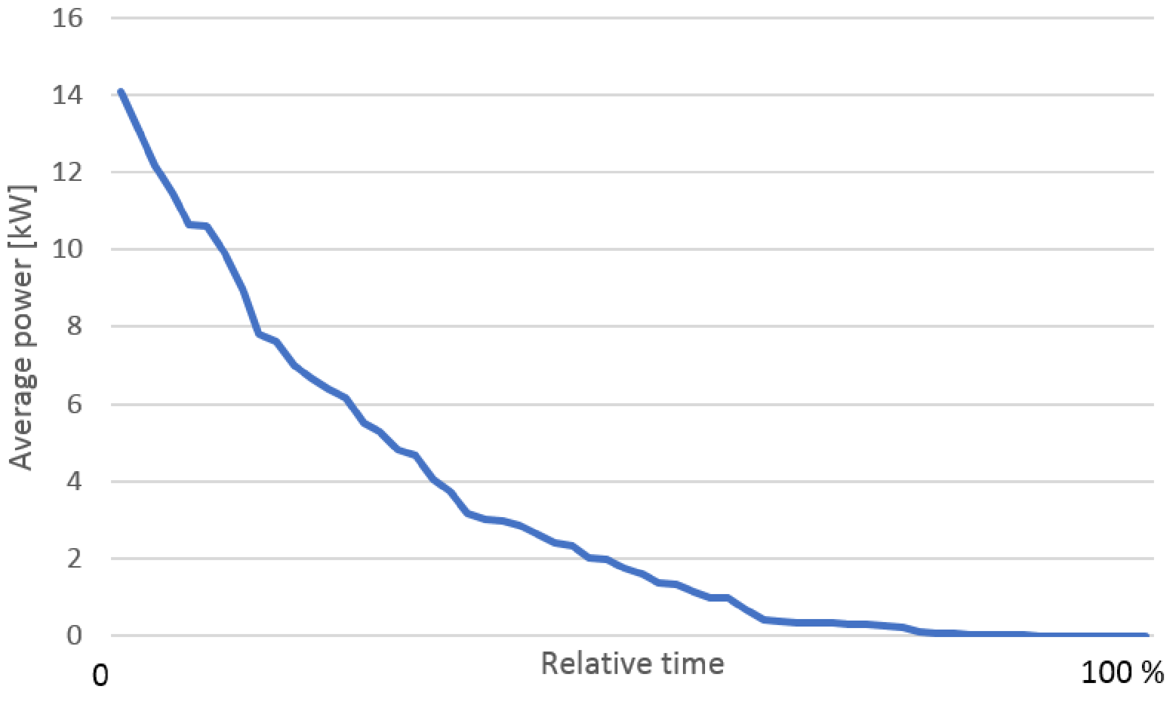

Figure 2: Distribution of average power for five years

Detailed analysis of techniques to increase the efficiency was published in previous papers [9] and [10]. To sum up the main conclusion from these papers, the efficiency of a hydro turbine might be changed with various speed of rotation, and the efficiency of an induction generator could be improved by changing stator voltage. Additionally, to change the speed of rotation is necessary to change the frequency of the stator voltage. It leads to result that some device which could be able to change the stator voltage amplitude and frequency is needed. For this issue, a back to back converter could be used [11].

3 BACK TO BACK CONVERTER DESIGN

The back-to-back converter consists of two three-phase inverters connected by DC-link. It is commonly known power converter which can deliver energy in both directions, it can change voltage and frequency, and it can control the power factor of the grid. Simplified schematic of the power part of the converter is depicted in Figure 3:.

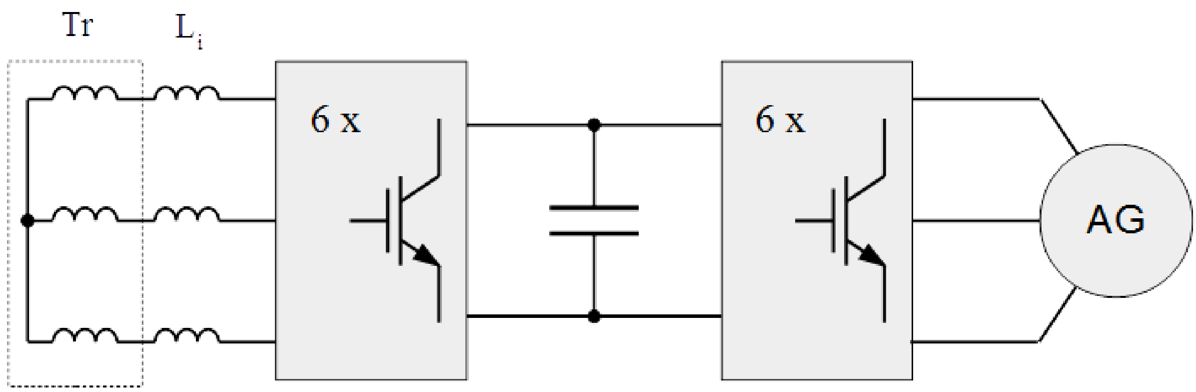

Figure 3: Schematic diagram of back to back converter, where L_i is input inductor and Tr is distribution transformer

One of the first step in design is selection of suitable transistors. Back to back converter is connected to the three-phase grid, so the minimum DC link voltage must be higher than rectified voltage of three phase grid [12], calculated as:

$$U_a = U_p \cdot \sqrt{3} \cdot \sqrt{2} \cdot G_t = 230 \cdot \sqrt{3} \cdot \sqrt{2} \cdot 1{,}1 = 622\ V \qquad (1)$$

Where U_a is maximal voltage and U_p is effective value of one phase voltage and G_t is grid voltage tolerance. It is clear, that maximal transistor voltage must be higher than 600 V. The IGBT six-pack transistor module with maximal collector emitter voltage 1200 V was chosen. The maximal current was set as 150 A, according to operate with induction machines with power up to 30 kW. Finally, the six-pack module FS150R12KT3 from Infineon company was used.

DC-link capacitor does not have to compensate the macroscopic wave of the current, because it is eliminated by three phase inverter which provides macroscopic constant current. Current is waved only microscopic during the PWM switching. DC-link capacitor must eliminate this high frequency waves. The dimensioning of the DC-link capacitor is detailly described in [13]. Result is to use one DC-link film capacitor with capacity 480 μF and 4 IGBT snubbers with capacity 1,5 μF. These components are placed on one power printed circuit board, depicted in Figure 4:. The completed PCB with component is pictured in Figure 5:.

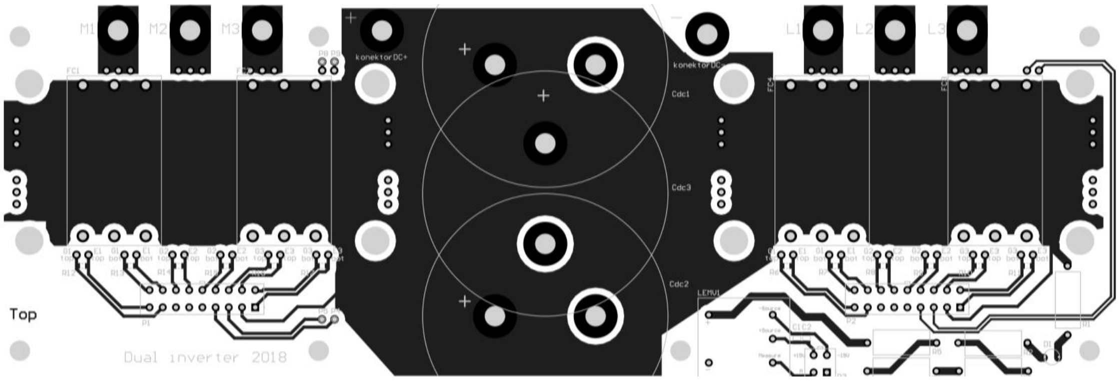

Figure 4: Power stage PCB of back to back converter

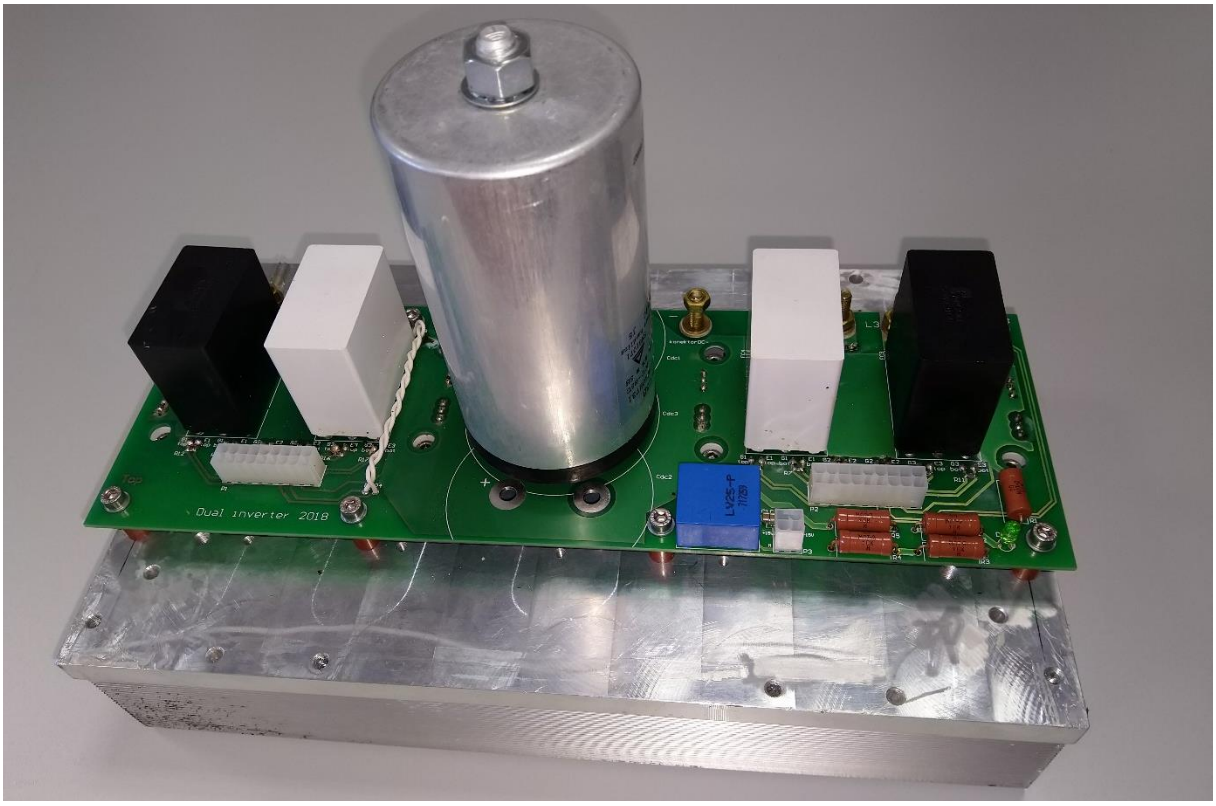

Figure 5: Completed power stage PCB of back to back converter

The IGBT six-pack will be driven by power management modules 2SC0435 from Power Integrations company. These modules drive the transistors and manage some protection of them. Control of the power modules will be realized from ST microcontroller that will control both inverters, synchronize their PWM and regulate stator voltage and frequency on an induction machine.

An induction machine will be connected directly to the back to back converter, only with measurement of the current. On the side of three phase grid, the filtration of PWM will be needed.

4 CONCLUSION

The back to back converter is one of possibility how to increase efficiency of small hydro power plant with various river flow. This paper shortly described design of this type of converter. Fabricated PCB were demonstrated, and next steps of design was mentioned. This converter will used to make experiments on small hydro power plants to verify the hypothesis about this way of improving the efficiency, what is the future research.

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