IMPLEMENTATION OF FAST RESPONSE CONTROLLER FOR BRIDGELESS BUCK CONVERTER WITH IMPROVED POWER FACTOR

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ABSTRACT

Active power factor correction (PFC) converters are widely applied in power electronic equipment to meet the rigorous international input current harmonics standard like IEC 61000-3-2 limits. Commonly, the boost converter is the most popular option as the PFC front-end because of its simple topology, excellent current-shaping performance, easy control and low cost.

Keywords: Congestion management, Deregulated Electricity market, Transmission Congestion Distribution Factor.

1 INTRODUCTION

Since the industrial times, we have relied on fossil fuel, gas fired power stations and power plants to generate electricity. However, these kinds of power generation options are no longer sustainable due to the negative impact they have on our planet. Therefore, new and renew- able ways of generating electricity have been developed such as solar and wind generation. These new options of generating electricity have significantly less negative impact on our planet. They do however impact our power grid in a negative way.

Two things are absolutely critical when generating electricity: the generated energy must be equal to the energy that we consume and the power grids voltage and frequency must be constant. The previous ways of generating electricity have contributed with a sort of inertia to the power grid. This inertia has created a window of time for the power generation side to adapt to the changes in power consumption, making the power grid more robust and stable. The issue with the renewable power generation alternatives is that they do not create this inertia, thus having a negative impact on the power grid.

2 PROPOSED SYSTEM

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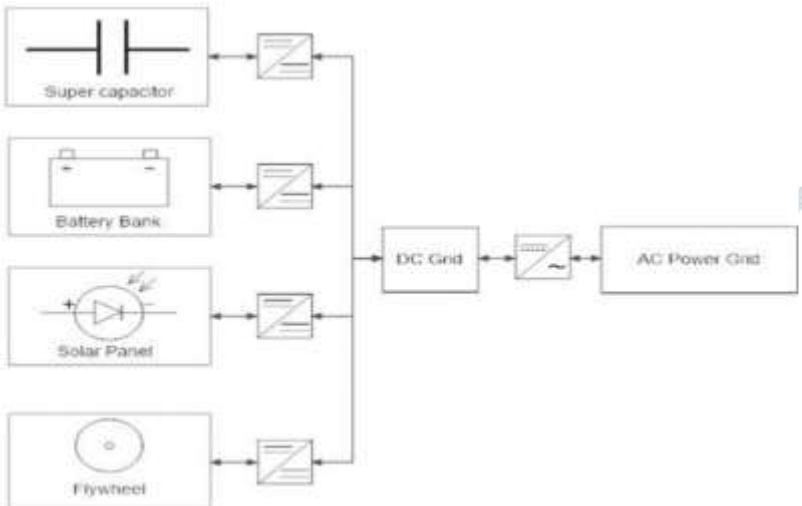

Figure 2.1 New Tropology

The purpose of the project is to design, simulate and build a general purpose single-phase bi-directional DC/DC converter. In order to accomplish this, the following goals have to be achiev

The bridgeless topology and the presence of only one or two semiconductor switches in the current flowing path during each interval of the switching cycle result in lower conduction losses compared with the conventional DCVM buck PFC rectifier. Hence, the electromagnetic interference noise emission is minimized. The converter achieves high power factor naturally with low total harmonic distortion in the input current. The output voltage of an arbitrary non ideal DC/DC converter contains both a DC and an AC component. The AC component or ripple occurs due to the switching operation of the converter and is in most cases undesired.

2.1 BLOCK DIAGRAM

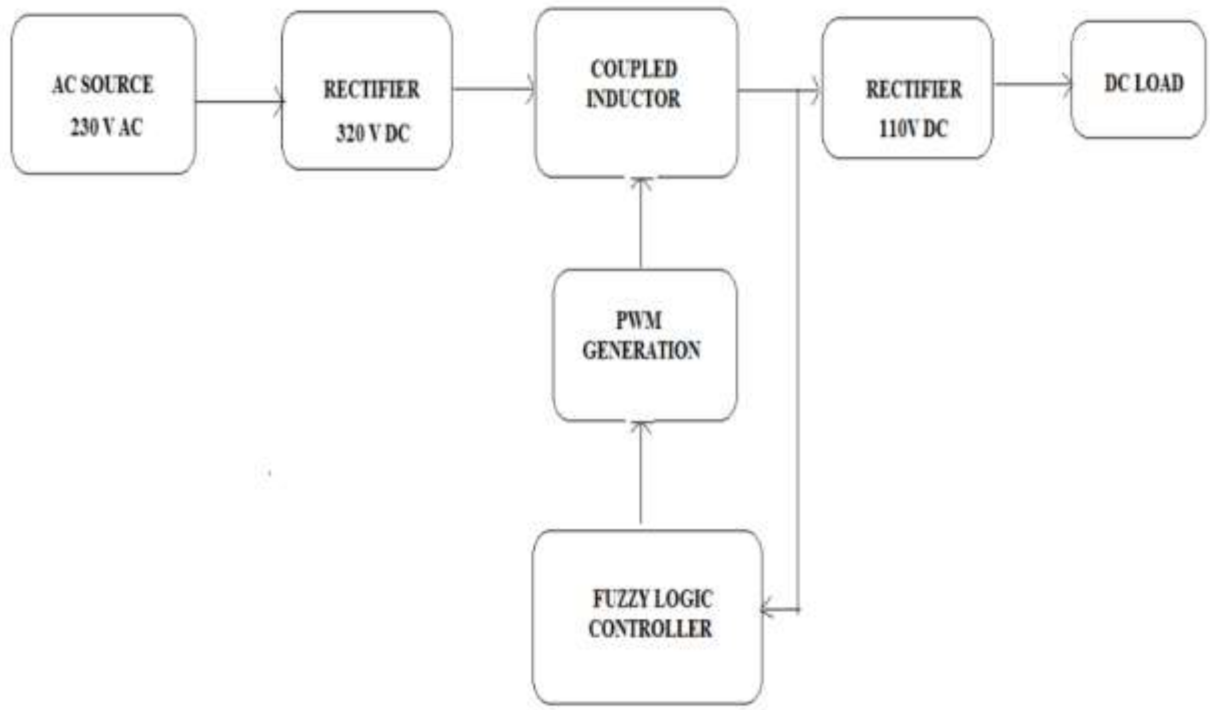

Figure 2.2 Block Diagram

The two coils may be physically contained in a single unit, as in the primary and secondary windings of a transformer, or may be separated. Coupling may be intentional or unintentional. Unintentional inductive coupling can cause signals from one circuit to be induced into a nearby circuit, this is called cross-talk, and is a form of electromagnetic interference.

2.1.1 RECTIFIER

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The reverse operation is performed by the inverter. The process is known as rectification, since it "straightens" the direction of current. Physically, rectifiers take a number of forms, including vacuum tube diodes, wet chemical cells, mercury-arc valves, stacks of copper and selenium oxide plates, semiconductor diodes, silicon-controlled rectifiers and other silicon-based semiconductor switches. Historically, even synchronous electromechanical switches and motors have been used. Early radio receivers, called crystal radios, used a "cat's whisker" of fine wire pressing on a crystal of galena (lead sulfide) to serve as a point-contact rectifier or "crystal detector.

2.1.2 COUPLED INDUCTOR

Two conductors are said to be inductively coupled or magnetically coupled when they are configured such that a change in current through one wire induces a voltage across the ends of the other wire through electromagnetic induction. A changing current through the first wire creates a changing magnetic field around it by Ampere's circuital law. The changing magnetic field induces an electromotive force (EMF or voltage) in the second wire by Faraday's law of induction. The amount of inductive coupling between two conductors is measured by their mutual inductance. The coupling between two wires can be increased by winding them into coils and placing them close together on a common axis, so the magnetic field of one coil passes through the other coil. Coupling can also be increased by a magnetic core of a ferromagnetic material like iron or ferrite in the coils, which increases the magnetic flux.

2.1.3 GENERATOR

Pulse width modulation (PWM), or pulse-duration modulation (PDM), is a method of reducing the average power delivered by an electrical signal, by effectively chopping it up into discrete parts. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load. Along with maximum power point tracking (MPPT), it is one of the primary methods of reducing the output of solar panels to that which can be utilized by a battery.[1] PWM is particularly suited for running inertial loads such as motors, which are not as easily affected by this discrete switching, because their inertia causes them to react slowly. The PWM switching frequency has to be high enough not to affect the load, which is to say that the resultant waveform perceived by the load must be as smooth as possible.

2.1.4 FUZZY LOGIC CONTROLLER

Fuzzy controllers are very simple conceptually. They consist of an input stage, a processing stage, and an output stage. The input stage maps sensor or other inputs, such as switches, thumbwheels, and so on, to the appropriate membership functions and truth values. The processing stage invokes each appropriate rule and generates a result for each, then combines the results of the rules. Finally, the output stage converts the combined result back into a specific control output value. The most common shape of membership functions is triangular, although trapezoidal and bell curves are also used, but the shape is generally less important than the number of curves and their placement. From three to seven curves are generally appropriate to cover the required range of an input value, or the "universe of discourse" in fuzzy jargon. As discussed earlier, the processing stage is based on a collection of logic rules in the form of if-then statements, where the IF part is called the "antecedent" and the then part is called the "consequent". Typical fuzzy control systems have dozens of rules.

2.1.5 DC LOAD

DC-to-DC converters are used in portable electronic devices such as cellular phones and laptop computers, which are supplied with power from batteries primarily. Such electronic devices often contain several sub-circuits, each with its own voltage level requirement different from that supplied by the battery or an external supply (sometimes higher or lower than the supply voltage). Additionally, the battery voltage declines as its stored energy is drained. Switched DC to DC converters offer a method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing.

Once a DC operating point is defined by the DC load line, an AC load line can be drawn through the point. The AC load line is a straight line with a slope equal to the AC impedance facing the nonlinear device, which is in general different from the DC resistance. The ratio of AC voltage to current in the device is defined by this line. Because the impedance of the reactive components will vary with frequency, the slope of the AC load line depends on the frequency of the applied signal. So there are many AC load lines. That vary from the DC load line (at low frequency)

2.1.6 PSS – PERIODIC STEADY STATE

Periodic steady state refers to the equilibrium condition that occurs after start-up when a circuit has stabilized and transients no longer influence the circuit.

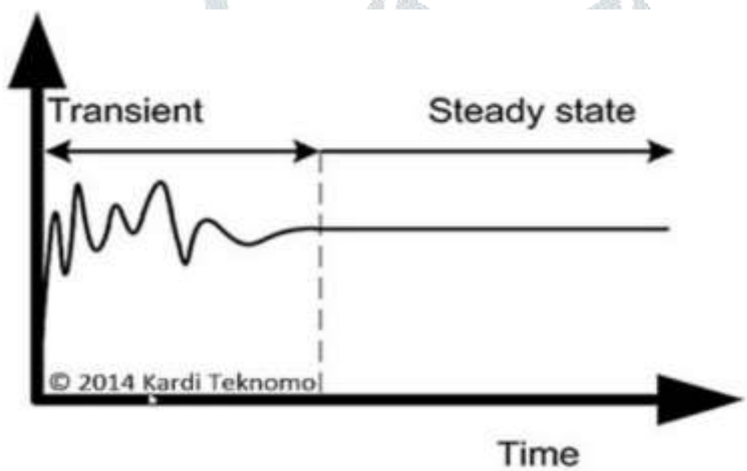

Figure 2.3 Periodic Steady Stat

3 RESULTS

A suitable bi-directional DC/DC converter topology was found for the desired system that fulfills the Topology requirements in Section 3.1. A two layered PI controller system that fulfills the System requirements in Section 3.1 was implemented, simulated and tested. Fi- nally, a system was built that fulfills the System requirements in Section 3.1.

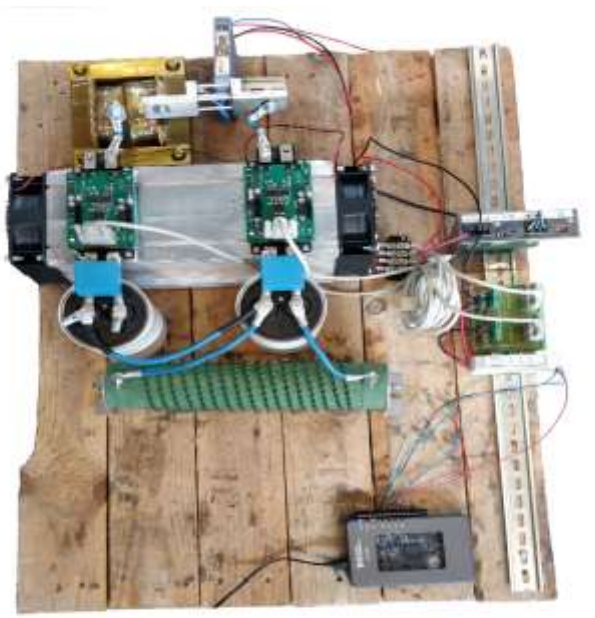

Figure 3.1 Entire system – DC/DC bidirectional converter

3.1 SIMULATIONS

In the simulation tests, the DC-bus is referred to as the ”A-side” and the super capacitor is referred to as the ”B-side”. Also all step responses occur after one second if nothing else is stated.

3.1.1 SIMULATION TEST 1: A → B - BUCK MODE

The resulting voltages and currents of a 10 V step response . In this test the super capacitor voltage is initially far lower than the voltage on the DC-bus.

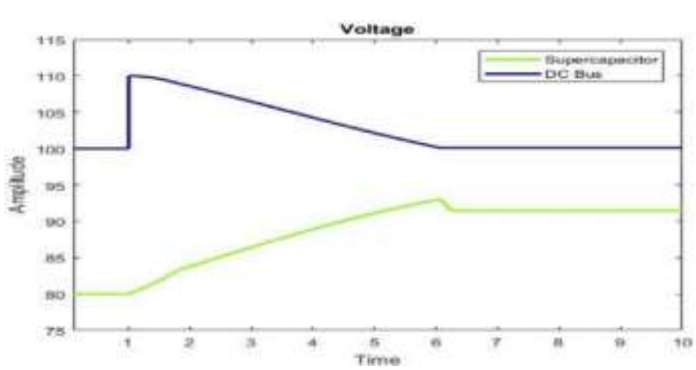

Figure 3.2 The super capacitor and DC-bus voltages

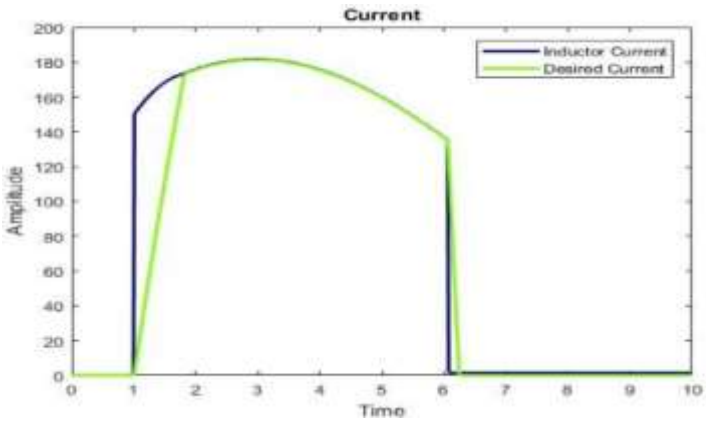

Figure 3.3 The inductor current and the desired current from the controller

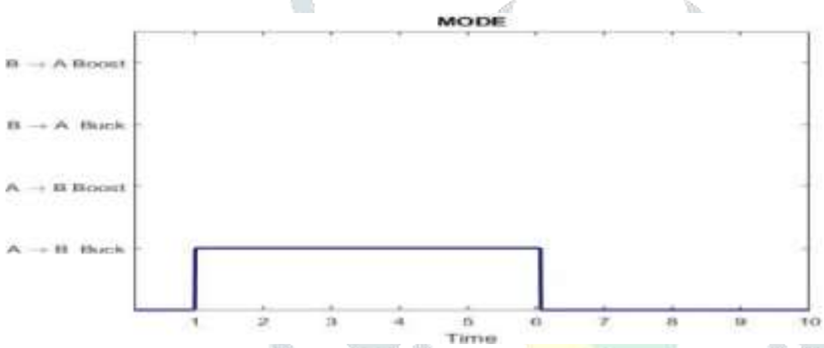

Figure 3.4 The four modes of the DC/DC converter

The current starts to flow from the DC-bus to the super capacitor until the voltage on the DC-bus is stabilized around 100 V. The slow increase of the current, relative to the desired current, is caused by the systems large inductance and the simple nature of the controller (See more a

Due to the increased voltage on the DC-bus, and since the super capacitor voltage is lower than the DC-bus voltage, the system is operating in Buck mode (A B) .

When the initial voltage of the DC-bus and the super capacitor was set to 100 V and 80 V, it took 5.056 seconds for the system to adjust to the 10V step response whilst in Buck mode.

3.1.2 PRACTICAL TEST 3: SIGNAL CONVERSION – SHOOT THROUGH PROTECTION

In this test, the driver cards protection circuitry is tested and verified. Two signals are sent to the driver card and the resulting gate voltage.

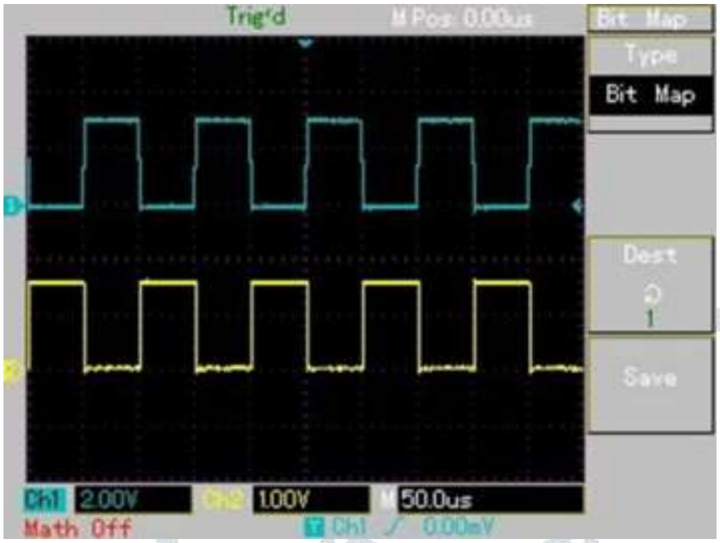

Figure 3.5 Two control signals

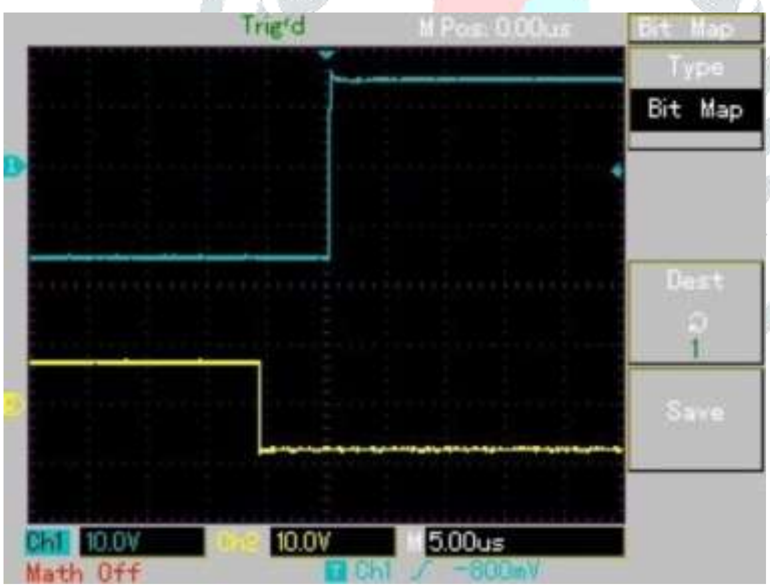

Figure 3.6 Delayed gate signal

Even though the control signals are each other's inverse, the resulting gate signals are separated by a 6 us time window. Thus protecting the driver card from shoot though when switching between the two IGBTs.

4 CONCLUSION

4.1 POWER TRANSISTORS: MOSFET VS IGBT

In the early stages of this project, the idea was to use the SKM350MB120SCH15 Silicon Carbide (SiC) power MOSFETs instead of the CM200DX-24S IGBTs. Historically, the traditional MOSFET has been able to switch a lot faster than the IGBT, but at much lower effects. However, these new Silicon Carbide power MOSFETs are designed for similar, if not higher, voltage and current levels than IGBTs and they offer a lot higher switching frequency., the SKM350MB120SCH15 is far superior to the CM200DX-24T and the most important difference is the significantly lower gate charge, QG, that is required. The lower gate charge makes the increased switching frequency possible and would put less stress on the gate driver IC. Unfortunately, the SiC power MOSFETs were not available for purchase and therefore the CM200DC-24T modules were used instead. But due to the flexibility of the driver IC and the constructed driver PCB, the design PCB could still be used to control a SiC power MOSFET as long as the pin configuration is the same.

4.1.1 DIMENSIONING THE INDUCTANCE

Generally when designing a DC/DC converter, the goal is to have a switching frequency that is as high as possible, and by doing so reducing the inductor size. However, the inductors size serves another purpose in high effect DC/DC converters: it determines how fast the current flow can change. When the voltage difference between the two sides of the converter is high and it starts to switch, the initial current can be extremely high as . If the current isn't properly limited by the inductance, these transients could have a devastating effect on the power transistor and driver IC. It is very important that the measurement device is fast enough to detect the current transients, otherwise the current controller won't be able to safely control the system. Therefore, it is very important to find a balance between the switching frequency and inductor size and not use the smallest inductor allowed by the switching frequency.

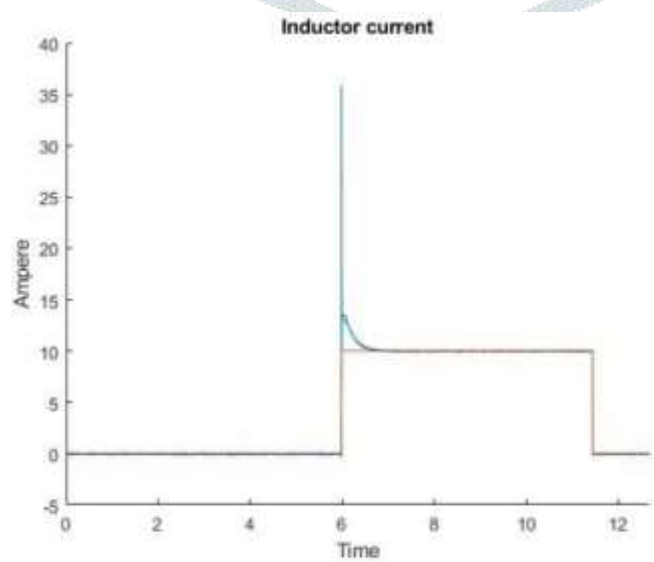

Figure 4.1 Current control – Transient

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