

HYBRID FEED FORWARD CONTROL FOR POWER FACTOR CORRECTION RECTIFIER

kavipriya.R¹, Chitravalavan²

¹P.G Student, Dept. of ECE, A.V.C College of Engineering, Mayiladuthurai, TamilNadu

²Professor, Dept. of ECE, A.V.C College of Engineering, Mayiladuthurai, TamilNadu

Abstract - Simple control architecture is realized using hybrid feed forward control for a Power Factor Correction (PFC) rectifier based on a four-switch buck-boost converter. The converter operates in repeated Conduction Mode, with gentle changes between the buck and the boost operations across a line-cycle. To implement the Power Factor Correction (PFC) functionality, the controller computes the buck and the boost duty cycles based on the sensed inductor current and output voltage. The power converter is simulated in Matlab Simulink. The various parameters such as efficiency and voltage regulations are recorded. This is achieved by designing a controller that controls the load as well as the Single-switch resonant dc/dc converter. To this end, a FUZZY controller is designed, which is integrated by a control associated with the dc load and a control related with the Single-switch resonant dc/dc converter. The controller works based on the reference voltage and the output voltage of the converter circuit. The control allows the constant dc load angular velocity to track a desired trajectory and also provides the desired voltage profile that must be followed by the output voltage of the single-switch resonant dc/dc converter. The FUZZY controller is tested through experiments using MATLAB -Simulink. The obtained results show that the desired voltage trajectory is well tracked under abrupt variations in the system guideline and that the controller is robust in such operation conditions, confirming the validity of the proposed controller.

Key Words: buck-boost converter, digital control, hysteresis control, continuous conduction mode, FPGA

1. INTRODUCTION

Operation is based on a voltage or current divider, are inefficient. They are limited to input voltages greater than the output voltage. Also, their power density is less because it needs low-frequency (50 or 60 Hz) line transformers and filters. Continuous regulators, provide a very high aspect output voltage. Their main area of application is at low power levels as low drop-out voltage (LDO) regulators. Electronic devices in continuous regulators conduct in their active modes. The dc to dc converters can be split into two main types: hard-switching pulse width modulated (PWM) converters, and resonant and soft-switching converters. Advantages of PWM converters include low component count, high efficiency, constant frequency operation, relatively simple mastery and economic availability of integrated circuit controllers, and power to achieve high alteration ratios for both step-down and step-up applications.

Pulse-Width Modulation (PWM) or Pulse-Duration Modulation (PDM) is a modulation method used to encrypt a message into a pulsing signal. Although this modulation technique can be used to encode information for transmission, its main use was to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. In addition, PWM is an one of the two principal algorithms used in photovoltaic solar battery chargers, the other being maximum power point tracking. The average value of voltage and current fed to the load was controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to off periods, the higher and total power supplied to the load.

The main advantage of PWM was that power loss in the switching devices was very low. When a switch is off there was practically no current, and when it on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel.

2. BACKGROUND RESERCH AND REVIEW

Most of the present technology and electronic equipment basically necessitate the function of a switching converter, particularly DC/DC and AC/DC converters. Switching converters find application where a fixed and regulated voltage source is of prime importance to deliver appropriate power consumption to the systems. Such systems include communications, computers, mobile technology, automobile industry, and some high-frequency switching converter applications. The main objective of switching converter is voltage regulation the ability to keep the output voltage stable in the event of input voltage and/or load current variations. Feedback control technique is used to achieve this goal. The voltage regulation of most DC/DC and AC/DC converters is dominantly accomplished using analog circuits. One of the reasons is that analog components can benefit more from simplicity, high bandwidth, and low cost. However, unfortunately, most analog circuits are very likely susceptible to environmental noise. In addition, the fast proliferation of digital integrated circuits, which requires lower supply voltage, programmability, less susceptibility to environmental variations, and fewer part counts, so the

performance and flexibility can be enhanced, has given the analog control a significant challenge incapable of achieving these requirements. Utilizing digital controller IC provides numerous advantages than analog IC. The research of digital-controlled power converter design now plays a very important role in the power electronics field.

The digital control techniques for power quality improvement have been discussed and also the modeling of a digitally controlled switching power supply system is presented. Simulation and experimental results add to the merits of the paper. Also FPGA module for PWM generator is presented with its advantages. From the research point of view all the main contributions to digital solutions for power supplies demonstrate control approaches with minimum hardware resources and reduced complexity. Feasibility of completely integrated digital controllers is demonstrated. The authors of the paper deals that the techniques presented beneficial to designers, users, manufacturers and research engineers dealing with power quality improvement research.

The excessive use of computers and telecommunication equipment has resulted in high demand for the switch mode power supplies. The fast growing market of clean and pollution free renewable energy domains like fuel cell, solar photovoltaic and wind energy rely on effective and efficient conversion of electrical power. Hence, the use of power electronic converters has become very common. In general, DC-DC converters are non-linear and time varying in nature and are subjected to varying line voltages and wide range of uncertain load changes. Due to these conditions, converter's performance deteriorates significantly. In spite of a lot of research on high performance control techniques for DC-DC power converters there exists a need for effective and flexible controllers which can perform tight regulation under unpredictable line and load disturbances. A boost type DC-DC converter in particular has an RHP zero that depends on the load, which is highly uncertain. Hence, from the control design perspective, this makes the control of boost converter a challenging task for the researchers and imposes limitation on the achievable performance. The transfer function approach, employed to mathematically model DC-DC power converters, is used to design most of the linear controllers. Methods available for modeling these DC-DC switching power converters are: (i) State space averaging method; (ii) Circuit averaging (iii) Averaged switch modeling .

3. Four-Switch Resonant Dc-Dc Converters

Simple control architecture to allow the four switch buck-boost converter to achieve PFC functionality. The converter is operated in Continuous Conduction Mode (CCM) across the line cycle and controlled using hybrid feed forward control. It is shown that to implement PFC operation, only two sensors (an inductor current sensor and an output voltage sensor) are required, as opposed to the requirement of three sensors in the traditional boost ac-dc converter,

simplifying hardware requirements. Additionally, the control architecture is relatively simple to implement, achieves automatic mode transition between the buck and boost modes with negligible or no input current distortion at the mode transitions, and can achieve good performance in terms of power factor and efficiency. The Ideal operation of the four-switch buck-boost converter acting as a PFC rectifier. The design criteria for selecting the converter component values. The converter comprises a buck stage and a boost that share the same inductor.

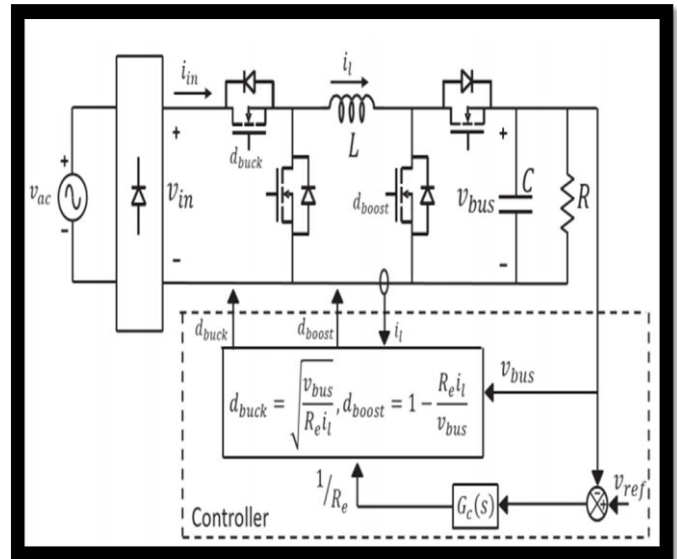


Fig.1 Block diagram

When the converter is used for PFC operation, the output voltage of the converter can be any voltage greater than zero, including lower than the peak input voltage. Thus, the converter operates in the buck mode when the input voltage is greater than the output voltage of the converter and the boost mode when the input voltage is less than the output voltage. For ideal operation of this converter, the mode transition should happen instantaneously when the input line voltage is equal to the output voltage of the converter. Two important considerations associated with this converter topology selection and energy buffering capacitor selection are discussed below. The four switch buck-boost converter can be realized as a synchronous or as an asynchronous converter, the converter remains in the Continuous Conduction Mode (CCM) over the entire line cycle. On the other hand, in the asynchronous version, the converter can operate in both CCM and discontinuous conduction mode (DCM).

3.1 RESISTIVE DC LOAD

The load resistance or, more generally, the load impedance is the equivalent resistance of the device attached to the output of a given circuit or system. For instance, the equivalent impedance of a loud speaker is the "load impedance" of an audio amplifier. Common room loud speakers' impedance, but this varies with frequency, and

often some resistors and capacitors are attached in parallel with the loudspeakers to "build" the rated impedance of 8Ω . An example of a typical loudspeakers' impedance curve is below: it varies somewhat "wildly" with the frequency. So, this is the load impedance seen by an audio amplifier. As another example, the equivalent resistance of a toaster is a "load resistance" attached to your home power grid when you are having tea and roasting toasts. In general, the load resistance can be the input impedance of some other circuit mounted in cascade at the output of the circuit "which is being loaded". This happens in multistage amplifiers. The picture below depicts this general case: the destination block is the load impedance of the source block which models a generator.

4. PRINCIPAL OF WORKING

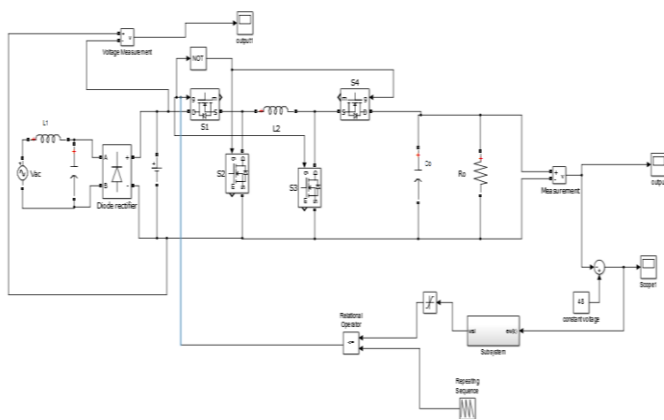


Fig.2: Implementation Diagram

4.1 EQUIVALENT CIRCUIT

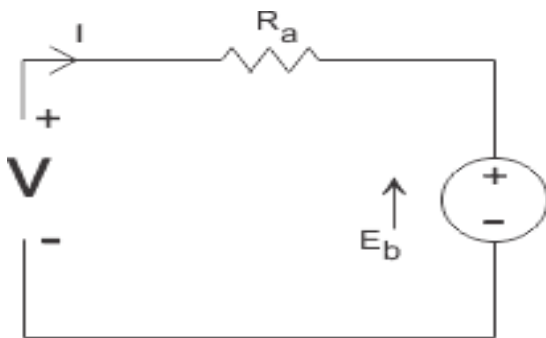


Fig 3: Equivalent Circuit of Resistive DC Load

As in RESISTIVE load the field is produced by resistive; there is no need of drawing field coils in the equivalent circuit of resistive dc load. The supply voltage to the armature will have armature resistance drop and rest of the supply voltage is countered by back emf of the load. Hence voltage equation of the load is given by,

$$V = IR + E_b$$

Where I, is armature current and R is armature resistance of the load. E_b is the back emf and V is the supply voltage.

4.2 FUNDAMENTAL OF FRACTIONAL CALCULUS

Fractional calculus is an old mathematical topic since 17th century. Fractional calculus is a subdivision of calculus theory which generalizes the derivative or integral of a function to non -integer order. Fractional calculus helps evaluating (d^ny/dt^n) n-fold integrals where n is fractional, irrational or complex. For FUZZY systems n is considered to be fractional. The number of applications where fractional calculus has been used rafuzzly grows. These mathematical phenomena allow describing a real object more accurately than the classical "integer-order" methods. The real objects are generally fractional however, for many of them the fractionality is very low. The main reason for using the integer -order models was the absence of solution methods for fractional differential equations. At present there are lots of methods for approximation of fractional derivative and integral and fractional calculus can be easily used in wide areas of applications (e.g.: control theory - new fractional controllers and system models, electrical circuits theory - factices, capacitor theory, etc.).

The theory of fractional-order derivative was developed mainly in the 19th century. There are several definitions of fractional derivative. Two important and widely applied definitions are: Grunwald-Letnikov definition is perhaps the best known one due to its most suitable for the realization of discrete control algorithms.

The Grunwald-Letnikov definition is:

$${}_a D_t^\alpha f(t) = \lim_{h \rightarrow 0} h^{-\alpha} \sum_{j=0}^{\lfloor \frac{t-a}{h} \rfloor} (-1)^j \binom{\alpha}{j} f(t - jh)$$

Where $[x]$ means the integer part of x and h is time step.

The Riemann-Liouville definition is given as:

$$f(t) = \frac{1}{\Gamma(n - a)} \frac{d^n}{dt^n} \int_a^t \frac{f(\tau)}{(t - \tau)^{\alpha - n + 1}} d\tau$$

For a wide class of functions which appear in real physical and engineering applications, the Riemann-Liouville and the Grunwald - Letnikov definitions are equivalent.

4.3 FUZZY CONTROL SYSTEM

A FUZZY controller is represented as FIS. It allows us to adjust derivative (λ) and integral (μ) order in addition to the proportional, integral and derivative constants where the values of λ and μ lie between 0 and 1. This also provides more flexibility and opportunity to better adjust the dynamical properties of the control system. The FUZZY controller gives good robustness. The robustness of fractional controller gets more highlighted in presence of a non-linear actuator. Fig. 2.2 shows the concept of a fractional FUZZY control system.

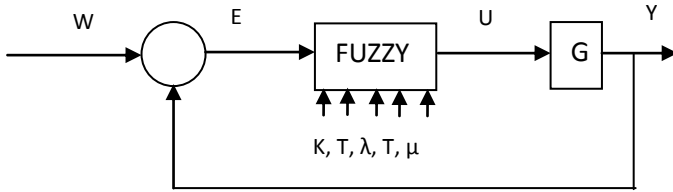


Fig 4: FUZZY control system

Applying Laplace transform to this equation with null initial conditions, the transfer functions of the controller.

Taking $\lambda=1$ and $\mu=1$, we can obtain a classical FUZZY controller. If $\lambda=0$ we obtain a PD ^{μ} controller, etc. All these types of controllers are the particular cases of the PI ^{λ} D ^{μ} controller. Actually, in theory, itself is an infinite dimensional linear filter due to the fractional order in differentiator or integrator.

It can be expected that controller may enhance the system control performance due to more tuning knobs introduced. Actually, in theory it is an infinite dimensional linear filter due to the FUZZY.

5. SIMULATION RESULTS OF RESISTIVE CONTROL USING FUZZY CONTROLLER

5.1 MATLAB

MATLAB is one of the most successful software packages currently available. It is a powerful, comprehensive and user friendly software package for simulation studies. A very nice feature of Simulink is that it visually represents the simulation process by using simulation block diagram. Especially, functions are then interconnected to form a Simulink block diagram that defines the system structure. Once the system structure is defined, parameters are entered in the individual subsystem blocks that correspond to the given system data. Some additional simulation parameter must also be set to govern how the computation is carried out and the output data will be displayed.

5.2 DEVELOPMENT ENVIRONMENT

It incorporates a set of tools and facilities that allows the use of MATLAB function and files. Most of these tools are of graphical user interface in nature. It includes the MATLAB desktop, a command window, a command history, editor, debugger and browsers for viewing help, the workspace, files and the search path.

6. CONCLUSION

Motivated by the FUZZY controller approach applied in the mobile robotics area, a solution for the voltage trajectory tracking problem for the Single-switch resonant dc/dc converter DC load system was presented. According to the simulation results, the voltage of the load tracks a desired voltage trajectory. The obtained results have shown the

robustness of the FUZZY controller when uncertainties occur in the system's power supply E, the converter load R, the inductance L, and the capacitance C, as well as in the coefficient b, control signal θ , and load voltage. It is important to underline that these types of abrupt variations do not happen in practice at the same time, or with such large variations regarding their nominal values. However, this system were undertaken to demonstrate that the proposed controller presents a good performance under abrupt variations associated with the system parameters, which would make possible the introduction of this controller in practical applications.

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