Simulation of a Controller for 3 Phase Rectifier with Unity Power Factor for Microgrid

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Abstract— Nowadays it has become necessary to increase the use of renewable energy sources. However, the main disadvantages of RES are the uncontrollability and limited availability, depend on weather conditions. The application of DSP processors for energy management system of renewable and non-renewable energy sources intended for grid connected applications is presented here. The presented scheme explains the generation of PWM gated pulse signals using the Texas Instrument’s DSP with the help of MATLAB Code/Simulink and Code Composer Studio. The main components for the switching and regulation of the power sources are DC-DC and AC-DC converters. The mathematical model and state space equations for a small signal model of boost converter operating in continuous conduction mode and 3 phase rectifier for unity power factor are developed. Based on the transfer function controllers are designed and implemented it on TMS320F28335 DSP processor with the help of MATLAB Simulink and CCS. The proposed design ensures good tracking performances and maintains stability in the system. Since the control methods allow real time modification in the required reference according to the change in required output. Designed controller capabilities, load voltage variations and inductor current variations are demonstrated through MATLAB simulation results.

Keywords— Renewable Energy Sources (RES), Pulse width modulation (PWM), Digital Signal Processor (DSP), Code composer studio (CCS).

I. INTRODUCTION

A Micro-grid is a discrete energy system consisting of distributed energy sources (including demand management, storage, and generation) and loads capable of operating in parallel with, or independently from, the main power grid. The micro-grids are smaller versions of the traditional power grid. Like current electrical grids, they consist of power generation, distribution, and controls such as voltage regulation and switch gears. However, micro-grids differ from traditional electrical grids by providing a closer proximity between power generation and power use, resulting in efficiency increases and transmission reductions. Micro-grid also integrates with renewable energy sources such as solar, wind power, small hydro, geothermal, waste to energy, and combined heat and power systems [1].

The demand for energy, particularly in electrical forms, is ever-increasing in order to improve the standard of living. Power electronics helps with the efficient use of electricity. Thereby reduce power consumption. In recent years, the field of power electronics experienced a large growth due to confluence of several factors. The controller consists of linear integrated circuits/digital signal processors but the revolutionary advances in microelectronics methods have led the development of such controllers. Moreover these advances in semiconductor fabrication technology have made it possible to significantly improve the voltage and current handling capabilities and the switching speed of power semiconductor devices. These devices are used as switches for power conversion or processing [2].

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Modern electronic systems require high-quality, small, lightweight, reliable, and efficient power supplies. Linear power regulators, whose principle of operation is based on a voltage or current divider, are inefficient. This is because they are limited to output voltages smaller than the input voltage, and also their power density is low because they require low frequency (50 or 60 Hz) line transformers and filters. Linear regulators can, however, provide a very high-quality output voltage.

Their main area of application is at low power levels. Electronic devices in linear regulators operate in their active (linear) modes, but at higher power levels switching regulators are used. Switching regulators use power electronic semiconductor switches in on and off states. Because there is a small power loss in those states (low voltage across a switch in the on state, zero current through a switch in the off state), switching regulators can achieve high energy conversion efficiencies. Modern power electronic switches can operate at high frequencies. The higher the operating frequency, the smaller and lighter the transformers, filter inductors, and capacitors.

The main objective of this paper is to present DSP-based energy management system and development. The hybrid energy sources are connected parallel with auxiliary power unit for storage and to improve transient and system stability to achieve dedicated control system [7]. The dedicated control system is designed with help of the DSP processor TMS320F28335 and uninterruptible power supply is designed. This hybrid combination of power supplies provides better static and dynamic response of the system.

![Figure 1. Block diagram of Micro-grid for Boost converter and 3 phase rectifier [7].](image)

It was concluded and suggested in our previous paper [1], the use of active filter for 3 phase rectifier and voltage/current control mode for boost converter, based on DSP processor to have lossless and regulated output. The main components for the switching and regulation of the power sources are DC-DC and AC-DC converters. The conventional three-phase rectifier with bulky LC output filter has been widely used in the industries. By eliminating the bulky LC filter and replacing it with Power electronic device rectifier without losing most of the advantages of the conventional rectifier, very high power density power conversion with high power factor can be achieved. Operation principle and design considerations are illustrated and verified by MATLAB simulation for 3 phase rectifier to have regulated output for the load and unity power factor at supply side. The testing of the designed processor is done with software and a DSP using different platform for programming and simulation. Figure 1 shows block diagram of Microgrid with different power electronic devices.
A conventional boost converter employed with the different sensors, output voltage and inductor current is fed back to the DSP processor through analog to digital convertor. The TMS320F28335 DSP processor is programmed with the C code generated by the embedded coder which the implementation of MATLAB Simulink model using code composer studio. The code written in C language for the processor provides flexibility in changing the frequency of PWM pulse. To write code in C language in code composer studio is a problematic and tedious job rather it is very easy to create a model in MATLAB/Simulink and then convert it to C language using embedded coder [1].

The structure of the paper is as follow. In section II, the complete description of DSP peripherals and the implementation of the algorithm for PWM pulse generation are discussed. In Section III, brief description of the controller and algorithm is discussed, and MATLAB simulation and Results are also explained in this section. The last section IV concludes the paper with final remarks.

II. MATLAB SIMULATION AND RESULTS

A. Three Phase Rectifier

For three phase input power factor correction, a boost converter is used at the output of the rectifier. Overall system efficiency is reduced as this DC-to-DC converter needs heavy filtering at the input. For a conventional three-phase bridge rectifier, low current distortion and unity power factor at the input are the most important design criteria. For AC-to-DC rectification via a capacitive filter, these criteria provide maximum throughput power with negligible ill effects. Rectification needs to be controlled precisely in order to obtain low-distortion input current at unity power factor. This is achieved through active power factor correction at the input of the rectifier, using Pulse Width Modulation [1]. PWM controls the input currents to make them sinusoidal and in phase with their respective input voltages. Thus power factor at the input is maintained close to unity.

![Three Phase Rectifier](image)

Figure 2. Three Phase Rectifier

B. Designed PI controller for 3 phase rectifier for unity power factor

In above control scheme Proportional-Integral (PI) controllers are used in order to minimize the input error signals. The error signals are derived by calculating difference between reference set point and feedback signals. For the implementation of dynamic system control; Park and Inverse Park transformation are used i.e. control signal which is used for PWM generation is derived from Inverse Park transformation of Vd, Vq whereas control action takes place after Park transformation. Rectifier DC voltage is controlled by comparing it with DC voltage reference which will provide Idref (active power reference).

For unity power factor operation Iqref (reactive power reference) is maintained to zero. PI controller gains (Kp, Ki) are optimized for proper control action.
A Micro-grid with hybrid power supplies uses electronics devices to control and regulate the terminal voltage and current. The literature [1] suggests the use of digital controller for power electronics devices, instead of bulky and costly passive filters which makes the system uncontrollable. Here, Digital Signal Processor worked as a controller for boost converter and 3 phase rectifier with unity power factor to have regulated and efficient output. The proposed scheme is tested and verified with the help of MATLAB simulation and code composer studio.

The complete mathematical model developed and the control scheme is processed by a dynamic, fast in-response, real time processor TMS320F28335. Effectiveness of the proposed controller to generate PWM control signal is analyzed with MATLAB Simulation and implementing it on DSP processor with the help of code composer studio. The DSP based controllers application for different converters verifies the performance satisfactorily. These results demonstrate that controller guarantees to track the required output which is comparatively better than other works presented in various literatures.

It is almost impossible to have an algorithm suitable for all situations. It is, therefore, important to consider some of the situations for which the further study is required. The algorithm should include a multiple optimization process; practical application of this scheme may demand high computational integrity. Hence, the hardware implementation of proposed hybrid configurations is a challenging task. Hence, there is a scope to implement the suggested hybrid power system configurations in real time application.
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