Study of Digital Vs Analog Control

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***Abstract*— In an effort to gain a clear understanding of the effects of using digital control in place of analog control, this paper presents a collection of thoughts expressed in other such papers. This paper focuses on the benefits and consequences of using digital control over analog in distributed power systems and, to some extent, motor drives.**

I. Introduction

For many years, analog controllers have dominated the control of power electronics systems. Digital controls have continued to improve in cost and usability in the past several years. This has made digital controls more appealing to replace analog control in some devices. The benefits of adding digital control in power electronics are not based solely on adding performance to the individually controlled components, but in system monitoring capabilities. In a distributed power system it would be very helpful to have the controllers alert the operator of a potential problem. This is not achievable using traditional analog control. Also digital control allows for a more complex control scheme than what can be achieved with traditional control. An example would be using nonlinear control. Also digital control allows more flexibility for change. Unlike analog control, using a digital signal processor to control a system allows for reprogramming should the need arise without having to switch out hardware. With all this in mind there are still some issues associated with digital control. One major issue is the delay introduced with a digital controller. This paper will try to summarize a number of other papers that have addressed the issue of replacing analog controls with digital. While most of these papers discuss the issue in regards to systems other than those involved in a distributed power system, they still prove valid points either for or against digital control. For this reason they are still viable for study on this topic.

II. PROS OF DIGITAL CONTROL

There are several reasons why digital control is desired over analog control. These reasons also apply in converters and in distributed power systems as a whole. The following are citations directly from papers that address the digital pros over analog.

"Potential advantages of digital controller implementation include much improved flexibility, reduced design time, programmability, elimination of discrete tuning components, improved system reliability, easier system integration, and possibility to include various performance enhancements." [1].

"…the opportunity to realize non-linear, predictive and adaptive control strategies provides a strong reason why digital control could yield worthwhile advantages compared with traditional analog control concepts." [2]

"Some advantages of digital control are as follows:

(1) Digital components are less susceptible to aging and environmental variations.
(2) They are less sensitive to noise.
(3) Changing a controller does not require an alteration in the hardware.
(4) The provide improved sensitivity to parameter variations." [3]

"…analog control circuits of power electronics products are becoming digitalized because of improvements of the following undesirable characteristics;

-Difficulty in adjusting,
-Lack of flexibility to higher functions and system alteration,
-Low reliability, and so on" [4]

"Technological advances in digital signal processors (DSPs), networking, microprocessors, and programmable logic devices (PLDs) have empowered designers with entirely new techniques and methodologies that were economically unthinkable two decades ago. These advances, along with increased performance demands, have fueled the push of digital technology deeper into the controlled devices. The justification often quoted for this push to digital include reproducibility, increased stability, increased resolution, and decreased infrastructure costs (networks replace control wiring)." [5]

This work is supported primarily by the ERC Program of the National Science Foundation under Award Number EEC-9731677.

"Adaptive control remains inherently difficult using analogue systems. With digital current mode control, however, a variety of adaptive schemes are possible. … Access can be gained to most control parameters in software. … This gives potential for the investigation of other novel forms of adaptive control." After some cons were listed about digital control the paper goes on to say "… However, by taking proper care good system performance can be achieved." [6]

"The use of a Digital Signal Processor (DSP) and of Erasable Programmable Logic Devices (EPLD) make the board remarkably flexible and adaptive to different operation modes, requiring only software re-programming." [7]

As can bee seen there are a few main points that all people see as advantages over analog control. First being that the controls are able to realize more complex control processes. Anther advantage being that digital controllers can be reprogrammed to meet changing control needs when conventional analog controllers must be replaced. Another major advantage is that digital controllers are less sensitive to noise, which is good for power converters that switch at high frequencies. Also digital controls provide monitor capability to the system that is unheard of with analog controllers.

III. CONS OF DIGITAL CONTROL

With all the pros in mind of digital control over analog there must be some trade off. The following are citations directly from papers that address the digital pros over analog.

"Some of the disadvantages of digital control are as follows:

(1) Signal resolution due to finite word length of the digital processor.

(2) Limit cycles due to the finite word length of the digital processor or analog-to-digital (A/D) and digital-to-analog (D/A) converters.

(3) Time delays in control loop due to the computation of control algorithm by the processor." [3]

"Consequently, operating properties of the digital control system are inferior to an analog control system." [4]

"Using digital control introduces several features affecting the operation of the converter. Computation time, if 0 to 100% duty ratio operation is required, causes a two-cycle delay to be present in the current loop. To maintain an adequate phase margin, this delay must be accounted for in designing the current loop compensation. … Resolution is an issue in sampled data systems. For example, the duty cycle can only be set to a finite resolution, depending on the system clock frequency. Also, the accuracy of the inductor current and output voltage sampling directly affects the regulation and dynamic characteristics of the converter. … Finite word lengths for variables within the digital processor result in round off errors. Also, storing filter coefficients to finite precision affects the emulation accuracy of the digital compensators. Floating point processors may help to ease these constraints."[6]

As can bee seen there are a few main points that all people see as disadvantages over analog control. First being that there is a limited resolution of the feedback signal due to sampling done prior to the processor. Second is that limited word length available in the processor will limit the accuracy of the converted feedback signal. Lastly is the time delays introduced do to computations done in the processor.

IV. EXAMPLES THAT USE DIGITAL CONTROL OVER ANALOG

This section will bring forth quotes from several papers where digital control has already been used satisfactorily in place of analog. The following are citations from such works:

In the paper entitled "Partially Resonant Active Filter Using the Digital PWM Control Circuit with the DSP" it states that "… the digital control with the DSP is versatile and consequently, the power factor over 0.99 and a total harmonic distortion factor less than 1% are easily realized."[8]

In the paper entitled "Digital Control of a ZVS Full-Bridge DC-DC Converter" it states that "The extra costs introduced by the digital part of the control were found to be quite low; in some applications at least they can be offset by the fact that easy modification of the control are possible in software therefore avoiding expensive hardware changes." And it states, "The realized control shows that reliable operation of the converter is possible with a digital control scheme."[2]

In the paper entitled "Easy Digital Control of Three-Phase PWM Converter" it states that "As a result, this control method and the design techniques would be promising to offer digitally controlled converters with satisfactory performances good as far as the replacement of analog controllers is concerned."[4]

In the paper entitled "DSP-Based Fully Digital Control of a PWM DC-AC Converter for AC Voltage Regulation" it states, "In this paper a DSP-based (TMS320C14) fully digital controlled PWM inverter has been implemented to verify the proposed multiloop control scheme. The output voltage error for a step rated load change can be reduced to 5% within 5 sampling intervals when operating at 110V, 15A, and 60 Hz. Total harmonic distortion (THD) below 5% of a rated rectifier load at crest factor of 3 can be achieved. The constructed DSP-based PWM inverter system achieves fast dynamic response and with low total harmonic distortion (THD) for rectifier type of loads."[9]

In the paper entitled "An Integrated Digital PWM DC/DC Converter", it states that "…the architecture of a simple digital PWM DC/DC converter is presented. With no

external DSP or A/D converter is used. System complexity is greatly reduced without degrading performance. Thus all circuits can be integrated on a single chip." And it further states, "As shown in the simulation results, performance is acceptable in many applications."[10]

In the paper entitled "Digital Control Technologies for Modular DC-DC Converters", it states, "… initial research into using phase shift techniques to reduce filter size required for commercial DC-DC converters has proven very promising. Using a small, inexpensive microcontroller, we were able to significantly reduce the input current ripple generated by four DC-DC converters connected in parallel. The result is that the input filter's inductor size was reduced by 75%, and the capacitor size was reduced by 94%. It is clear that this technology will be an important component in reducing the size of modular power systems in the future." [11]

In the paper entitled "High Efficiency PWM Techniques for Digital Control of DC-AC Converters", it states, "Extensive simulation results as well as preliminary experimental tests have emphasized the validity of the fully digital solution adopted for inverter control."[12]

Finally in the paper entitled "Source Voltage Sensor-less Digital Control Using Observer for PWM Converter", it states, "A digital control method to obtain sinusoidal input current and unity input power factor without source voltage sensors has been presented. The input current control and the source voltage estimation are performed with two types of the observers. The phase synchronous control is based on the Fourier sires. The proposed system which are realized with very simple algorithms, offer an inexpensive and high reliable converter with good characteristics."[13]

V. Conclusion

It has been seen that there are several good things to advocate the use of digital control over analog. Also there are many points that show the problems involved with digital control. However, most of the problems with digital control can be over come or reduced to tolerable. This is seen in the many examples where people are already using digital control. This has been a summary of many papers that deal with this topic and was meant to help in the understanding of digital control. For a better understanding, reading all reference material would be beneficial.

Acknowledgment

This work is supported primarily by the ERC Program of the National Science Foundation under Award Number EEC-9731677.

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