Dual Active Bridge 컨버터를 위한 인공지능 적응형 Gain-scheduling PI 제어기

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Artificial Intelligence Gain-scheduling Adaptive PI Controller Scheme for Dual Active Bridge Converter

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ABSTRACT

This paper presents an artificial intelligence Deep Belief Network (DBN) gain scheduling adaptive PI controller scheme for dual active bridge (DAB) converter. The PI gains are allowed to vary within a predetermined range and therefore eliminate the problems faced by the conventional PI controller. The performance of the proposed controller is simulated and compared with the conventional fixed PI controller under various conditions. The experimental prototype of the DAB converter is implemented using a digital signal processor of TMS320F28335 manufactured by Texas Instrument to examine and to evaluate the performance criteria of the proposed controller. Simulation and experimental results show improvements in transient as well as steady state responses of the proposed controller over the conventional fixed PI controller.

1. Introduction

Despite the development in control theory, the majority of industrial processes are controlled by the well established proportional plus integral plus derivative (PID) controller illustrated in Fig. 1. The popularity of the PID control can be attributed to its simplicity in terms of design and from the point of view of parameter tuning and to its good performance in a wide range of operating conditions. The PID controller provides low cost, simple implementation, and when adequately tuned, it provides good dynamic behavior for the controlled process.

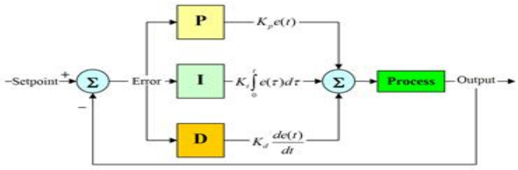

Fig. 1 Conventional PID Controller

However, the PID controllers present as a disadvantage, the need of retuning whenever the processes are subjected to some kind of disturbance or when processes present complexities such as non linearities. Therefore, over the last few years, significant development has been established in the process control area to adjust the PID controller parameter in an automatic way, in order to ensure adequate regulatory behavior for a closed loop plant[1].

In this paper, the parameter tuning task of conventional PID and gain scheduling PID controllers with dual active bridge (DAB) converters in a practical nonlinear process is assessed. The tuning procedure of controller gains utilizes artificial intelligence, such as neural network algorithm, in detail, a deep belief network (DBN).

2. Proposed AI Control Algorithm

Restrict boltzmann machine (RBM) can be stacked and trained in a greedy manner to form so called DBN. In Fig. 2, the DBNs are graphical models which learn to extract a deep hierarchical representation of the training data. They model the joint distribution between observed vector and the hidden layers[2].

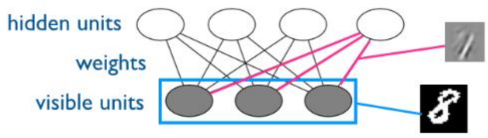

Fig. 2 Simple Generative Models of DBN

Each level has a conditional distribution for the visible units conditioned on the hidden units of the RBM and the visible hidden joint distribution is in the top level RBM. The principle of greedy layer wise unsupervised training can be applied to DBNs with RBMs as the building blocks for each layer.

For DAB converter, the DBN algorithm uses four input variables, input voltage, input current, output voltage, and output current, and it generates three state space output probabilities. Each state space probability indicates that a present system is located in which status like higher, same or lower than a reference point.

Using these probabilities, algorithm can calculate Ku which is the ultimate value for adjusting gain variables. At the end, each gain of the PID controller updates new gain value after Ku, which is illustrated in Fig. 3.

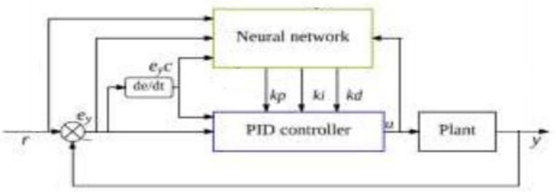

Fig. 3 Proposed Gain-scheduling PID Control Schema

3. Simulation and Experiment Results

To verify the proposed algorithm, simulation is conducted by PSIM and a 3.3 kW prototype DAB converter is implemented with following parameters in Table 1[3].

Table 1 Parameters for Simulation and Implementation

Vin, Vout	380V	Turn Ratio	24 : 24
Duty	50% t_d	Fs	50kHz
Lp (uH)	110 → 90	Lm (uH)	870 → 800
Load1(t=0.05s)	8.7A	Load2(t=0.1s)	8.7A
Pout : 3.3 kW			

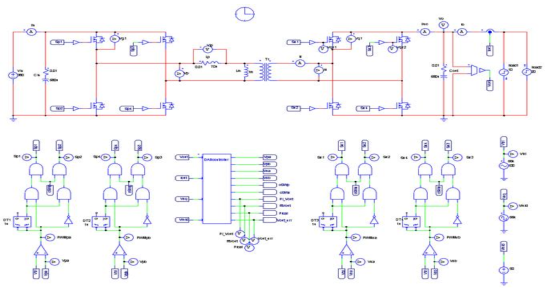

Fig. 4 PSIM Circuit Design

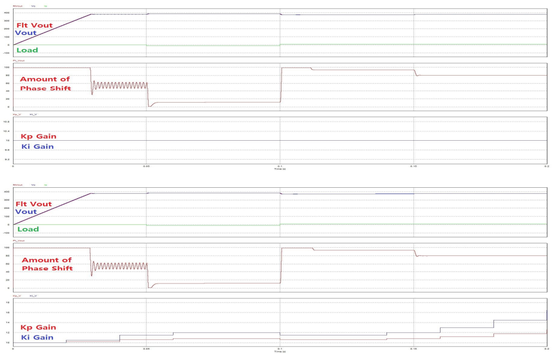

Fig. 5 Simulation Result
- Top :Conventional, Bottom :Proposed -

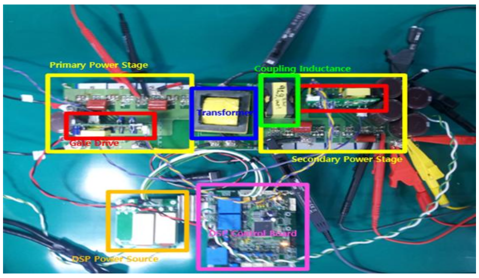

Fig. 6 Implemented DAB Converter

In the simulation of Fig. 4, load conditions are no load from the beginning, 8.7 A at t=0.05 and 8.7 A at t=0.1, respectively. Furthermore, components attenuation such as leakage degradation start at t=0.15. In Fig 5, step load response of proposed algorithm is improved as 20 us and steady state error decrease about 3 V.

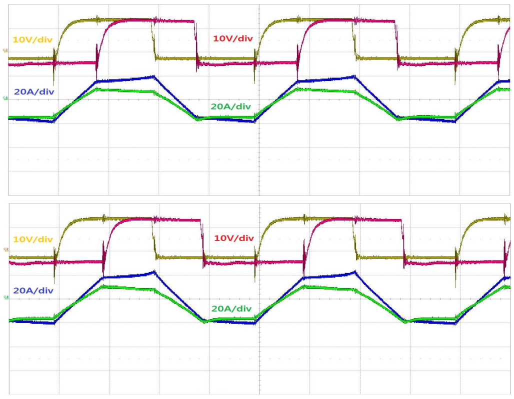

Fig. 7 Experimental Result
- Top :Conventional, Bottom :Proposed -

Fig. 6 shows the 3.3 kW prototype converter. In Fig. 7, the amount of phase shift is a little bit different around 3% under the same 3.3 kW full load. It comes from the gain variation of the PID controller, which shows that the proposed algorithm adjusts the gain value and reduces steady state error.

4. Conclusion

In this paper, a DSP based digitally controlled DAB converter is implemented using the artificial intelligence gain scheduling adaptive PI controller. This scheme is simulated digitally using CCS and PSIM and implemented using TI's TMS320F28335. The input voltage, input current, output voltage, and output current are used as input variables of the DBN algorithm. The calculated output variable of Ku changes the gains of PID controller. The results show that the regulation quality and the dynamic response are satisfactorily good.

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