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Feasibility analysis of fuzzy logic control for ITER Poloidal field (PF) AC/DC converter system

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HIGHLIGHTS

- The implementation of the Fuzzy controller for the ITER PF converter system is presented.
- The comparison of the FLC and PI simulation are investigated.
- The FLC single and parallel bridge operation are presented.
- Fuzzification and Defuzzification algorithms are presented using FLC controller.

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ABSTRACT

This paper describes the feasibility analysis of the fuzzy logic control to increase the performance of the ITER poloidal field (PF) converter systems. A fuzzy-logic-based controller is designed for ITER PF converter system, using the traditional PI controller and Fuzzy controller (FC), the dynamic behavior and transient response of the PF converter system are compared under normal operation by analysis and simulation. The analysis results show that the fuzzy logic control can achieve better operation performance than PI control.

1. Introduction

ITER (International Thermonuclear Experimental Reactor) is being played significant role in current international research and development of the fusion power. The ITER PF AC/DC converters provided the on-load voltage and current up to ±1.05_kV and ±55_kA. Due to the significant importance of Poloidal field (PF) converter provides DC current to superconducting coil for plasma position and shape control in vertical and horizontal trends [1]. The system parameters are mentioned in Table 1.

Topology selection is the fundamental for ITER PF converter system which is shown in Fig. 1. Two converters transformers were used to step down input power fed by four six pulse bridges [2].To validate the converter operation in four quadrants, mainly investigated the single and parallel mode.

The high current and voltage requirements to control the plasma, the ITER PF converters system were used six pulse phase control thyristor converters. Due to the inherent characteristics of the power converter, they are nonlinear and time varying in nature. Hence it is quite difficult to achieve the position of the plasma control using traditional PI controllers [3]. Therefore, to perform tight regulation need good controller to achieve under high load variation [4]. The concept change to adapt the fuzzy logic based control is suitable choice to achieve the desired load variation under different operation modes. The main advantages of such kind of fuzzy logic controller over the traditional PI controller: 1) no need to design accurate mathematical model; 2) inputs can be imprecise; 3) more suitable for nonlinear system; 4) More robust. To achieve a good performance, Fuzzy logic controller (FLC) implements very simple nonlinear controller, without using the complex realization.

In this paper a fuzzy logic control strategy is developed for high performance control of the ITER PF converter system. The model used in PF converter is a highly nonlinear system. Fuzzy logic established controller is known for their good performance, high quality

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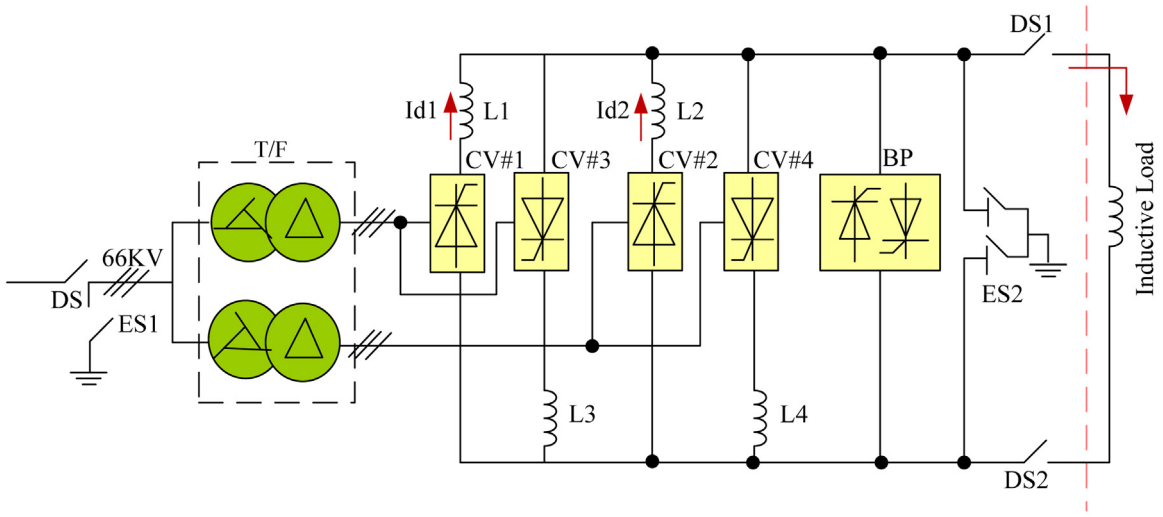

Fig. 1. Topology scheme of ITER PF AC/DC converter.

Table 1
Parameter for ITER PF converter prototype.

Parameter	Value
Converter Transformer	
Rated power	2*41 MVA
Voltage ratio	66 kV/1.05 kV
Short-circuit impedance	16%
DC reactor	
Inductance	200 μH
Resistance	275 μΩ
Dummy load	
Inductance	5.0 mH
Resistance	2.5 mΩ

of control, reliable, robust and good dynamic behavior. The outline of the paper is as follows. Section II describes the system operation of the PF converter. Section III explain the fuzzy logic approach to control the system. Section IV Fuzzification and inference rules. Section V Elaborates simulation results and Section VI is conclusion.

2. System operation strategy and design

The normal operation of the ITER PF AC/DC converter system in four quadrant operation is calibrated first. The Fig. 2 as illustrated the parallel mode, circulating current mode and single mode. Single bridge mode can be work as a transition between circulating to parallel or parallel to circulating. The different variables are used to control the input and output of the controller such as Vref is the input reference voltage which is compared with output voltage Vd. The input reference current Iref is compared with output load current Id.

Table 2 explains the normal operation rang of the ITER PF converter system, to illustrate the operation strategy to confine the plasma position for suitable range.

Fig. 2 and Table 3 show the operation state of the ITER PF AC/DC converter system. In circulating current mode the converter CV1 and CV4 performed operation in the region of A1 and A2 ($-10\%idn \leq id \leq 10\%idn$). In single bridge mode the converter CV1 and CV4 has been performed in the region of B1, $10idn < id \leq 30idn$ and B2($-30\%idn \leq id < -10\%idn$). Finally in parallel mode the converters CV1, CV2 and CV3, CV4 in the region of C1 id > 30%idn and C2 id < −30%idn performed the operation in parallel mode.

Table 2
Operation range.

Operational range	Parallel	Single	Circulating	Single	Parallel
Percentage (%)	<-30	−10 to −30	−10 to 10	10–30	>30

Table 3
Converters operation mode.

Converters	CV#1	CV#2	CV#3	CV#4
A1, A4	Circulating	0	0	Circulating
B1	Single	0	0	0
C1	Parallel	Parallel	0	0
A1, A4	Circulating	0	0	Circulating
B2	0	0	0	Single
C2	0	0	Parallel	Parallel

Table 3 validates the operation region and converter function. Horizontal rows show the converter units and vertical columns shows the operation region of the system.

2.1. The design requirements for the ITER PF control system

According to the plasma control design requirements for ITER PF converter system:

The current value for parallel operation mode design requirements should be

$$\left|\frac{(Id1 - Id2)}{Id1}\right| < 10\% \quad .$$

3. Fuzzy logic controls versus classical control

The conventional controller used numerical variables, which needs a complex mathematical model. Fuzzy logic based controller necessitates linguistic variable. Due to the highly composite interconnected system [5], it is slightly difficult to control both stability and dynamic response. Fuzzy logic based control is strong candidates to handle such kind of nonlinear system. Fuzzy logic expert system is the improved version of PI controller design [6]. In the closed loop feedback control system, error between feedback loop and reference can be labeled as zero and fuzzy membership is define as seven rules or sets like positive large, positive medium, positive small, negative large, negative medium, negative small and zero. The error difference between Vref and Vd and the current share PI fuzzy have been explained in Eqs. (1) and (2). The improvement in the conventional controller by used Fuzzy logic controller increase the reliability, fast dynamic response and convenient for high