NORMAL OPERATION AND FAULT ANALYSIS USING FUZZY CONTROLLER FOR ITER PF AC/DC SYSTEMS

[1]MAHMOOD UL HASSAN, [2]MUHAMMAD HUMAYUN, [3]LIANGSHENG HUANG, [4]PENG FU, [5]ZHIQUAN SONG, [6]XIUQING ZHANG

[1,3,4,5,6]Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China
[1,4]University of Science and Technology of China
[2]Shanghai Jiaotong University, China

Abstract - This paper proposed the normal operation and fault analysis of the ITER PF ac/dc converter system using fuzzy logic (FL). The analysis compares the performance of the PI and Fuzzy Controller (FC). The Short-Circuit faults analysis using fuzzy logic control scheme for (International Thermonuclear Experimental Reactor) ITER (Poloidal Field) PF ac/dc converter system are presented. The step response to the proposed scheme can verify. The analysis results validate the fuzzy logic control strategy is better than PI control.

Keywords - ITER PF, AC/DC Converter, Fault Analysis, Fuzzy Logic

I. INTRODUCTION

ITER PF converter system is the largest power supply system, which provides the DC current to superconducting coil to control the plasma shape and position [1].The ITER PF AC/ DC converters delivered the on-load voltage and current up to ±1.05_kV and ±55_KA [2]. The system parameters are given in Table 1.

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

Table 1 Parameter depiction for ITER PF

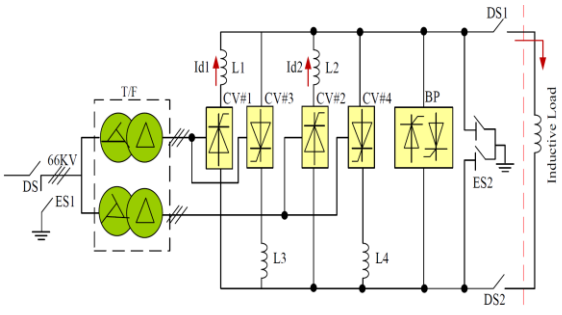


Fig.1. ITER PF AC/DC converter topology scheme

Fig.1. shows the proposed topology for the ITER PF converter system. The three-phase sources voltage 66kVhas been converted into 1.05kV by four six pulse bridges [3]. To validates the proposed technique normal and fault analysis mainly investigated by parallel operation mode. The high-power converter used in ITER PF converter is playing a significant rule. When supplying some critical power to loads, this power converter can provide continues current to superconducting coil even in fault conditions. The fuzzy base controller was designed to investigate the fault [4]. The main concern to supply critical load, these inverters in parallel mode should be able to continuous providing current, even faults has been occurred [6]. The high current and voltage supplies to control the high plasma, the ITER PF converters system is used to control the more robust control strategy. The power converter is nonlinear in nature, so it is quite difficult to control the position of the plasma and shape using traditional PI controller [4].Consequently, to achieve tight regulation essentially under high load variation needs good controller [5]. The idea changes to adapt the fuzzy logic approach-based control is appropriate candidate to realize the desired load variation on different operation modes. The main compensations for such kind of fuzzy logic controller of the conventional PI controller as is following:

1. The mathematical model was not required to design a controller, especially design some complex system;
2. Due to imprecise inputs;
3. More reliable to the nonlinear system;
4. Robustness.

This paper is mainly focusing the normal and fault operation for high performances of the ITER PF converter system. The PF converter model is highly nonlinear system. Fuzzy controller is recognized for good performance, high quality, robust and good dynamic behavior. The paper arrangement is as follows. Section 2 describes the fuzzy logic controller design algorithm. Section III Fuzzy controller Implementation strategy has been explained. Section IV verifies the simulation results by Matlab/ Simulink environment. Section V is conclusion.

II. FUZZY LOGIC CONTROLLER DESIGN

The normal four quadrant operation was investigated. The Fig. 2 is describing the operation range, like single bridge mode, parallel bridge mode and circulating bridge mode. The circulating operation is the transition state.

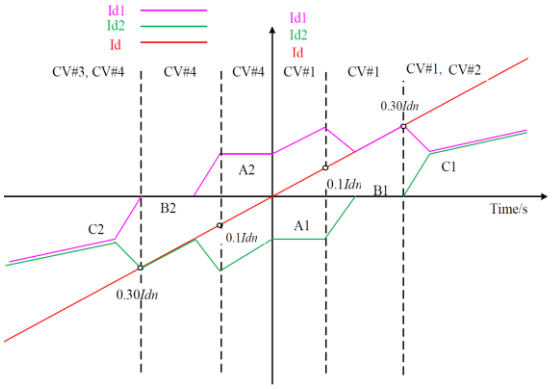


Fig.2. The ITER PF converter control scheme

The converter CV1 and CV4 works is circulating mode in the region $(-10\%\ \text{idn} \leq \text{id} \leq 10\%\ \text{idn})$. The converter CV1 and CV2 single bridge operation is described in the region $(10\text{idn} < \text{id} \leq 30\text{idn})and(-30\%\ \text{idn} \leq \text{id} < -10\ \%\text{idn})$. The CV1, CV2 and CV3, CV4 were performed in the region $\text{id} > 30\ \%\text{idn}$ and $\text{id} < -30\%\ \text{idn}$.

The conventional PI controller used in ITER PF controller system, need a complex mathematical model. Fuzzy controller used linguistic variable, due to the high complex ITER nonlinear system. Fuzzy controller is strong candidates to overcome the proposed problem. In parallel mode the current sharing control scheme was designed to provide 30% of the load current.

III. FUZZY CONTROLLER IMPLEMENTATION STRATEGY

Fuzzy logic is designing for ITER PF converter to overcome the complex mathematical problem. The crisp inputs to the fuzzy inference rule are converted into base membership function of the interval [0, 1]. Different levels or sets were partially defined error and change of error triangular membership functions as shown in Fig.3and Table 2. The controller implementation strategy has allocated into the following steps.

3.1 Fuzzification

Fuzzy controller is specially designing for linguistic variable, like IF-THEN rules are used instead of numerical values [7]. The error and change of error from the closed loop control system can be labeled such as (zero) ZO, positive small (PS), Positive medium (PM), Positive Large (PL), Negative Small (NM), Negative Medium (NM), Negative Large (NL) [8].The crisp input variable is converted into fuzzy variable is called fuzzification. For every input crisp variable, the fuzzifier can be find a specified membership value to calculate the linguistic variable.

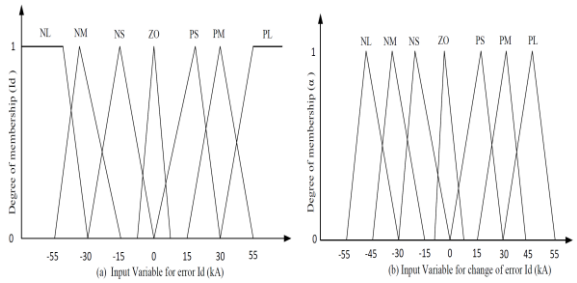


Fig.3. (a) Membership function for controlling error Id (kA) (b) Membership function to controlling for change of error Id (kA)

	Negative Large (NL)	Negative Medium (NM)	Negative Small (NS)	Zero (Z0)	Positive Small (PS)	Positive Medium (PM)	Positive Large (PL)
Negative Large	PL	PL	PL	PL	PM	PS	ZO
Negative Medium	PL	PL	PL	PM	PS	ZO	NS
Negative Small	PL	PL	PM	PS	ZO	NS	NM
Zero	PL	PM	PS	ZO	NS	NM	NL
Positive small	PM	PS	ZO	NS	NM	NL	NL
Positive Medium	PS	ZO	NS	NM	NL	NL	NL
Positive Large	ZO	NS	NM	NL	NL	NL	NL

Table 2 Control inference rules

3.2 Defuzzification

The average method is used in the proposed manuscript. Let be to define the output fuzzy variable from crisp value such as $\mu_{y\ldots}\,\mu_{yn}$ is a real number that can be expressed in terms attributes. Furthermore, the non-negative crisp value like $K_i \ldots K_n$ is called weights [9]. The equation (6) is defining the average method.

$$\left(\mu_{y1\ldots}\mu_{yn}, K_i \ldots K_n\right) = \sum_{i=1}^{n}\mu_y * K_i \qquad (1)$$

The weights should be satisfied by normalization function, which is given as $\sum_{i=1}^{n} K_a = 1$the output crisp value is given in equation

$$\text{Output} = \frac{\sum_{i=1}^{n} \mu_y * K_i}{\sum_{i=1}^{n} \mu_y} \qquad (2)$$

Where n is the total number of the excited rules, μ_y is the membership value, K_i and is the membership function for center value.

IV. SIMULATION RESULTS

The Matlab/Simulink simulation analysis is done. The ITER PF converter nominal parameters of the parallel operation were analyzed the effect of both controllers of FC and PI. The alpha variation and current sharing between the two converters were

shown in Fig. 4. In Fig. 4once the load changed accordingly, the firing angle alpha 1 and alpha 2 shown the response of the system. Fig. 5 shows the performance of both controller FLC and PI. The response shows FLC is better than PI.

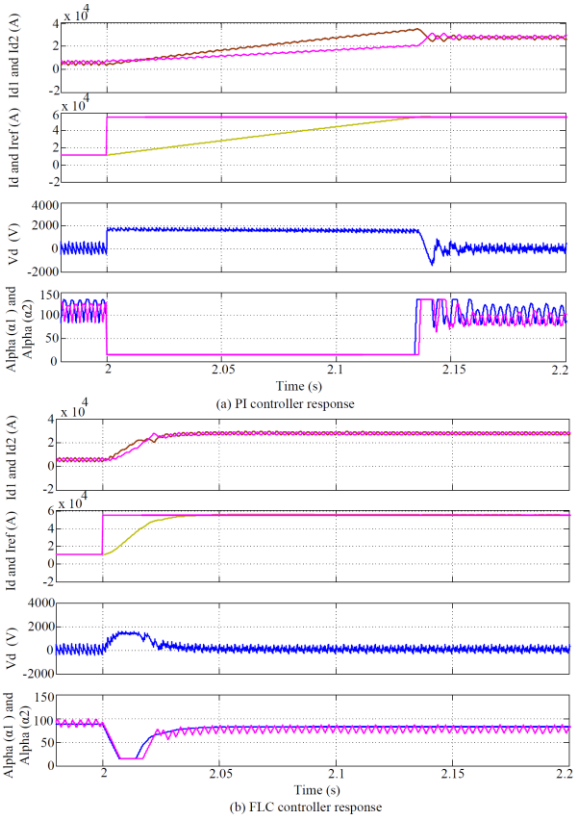


Fig.4. Parallel mode operation (a) PI controller (b) Fuzzy logic controller

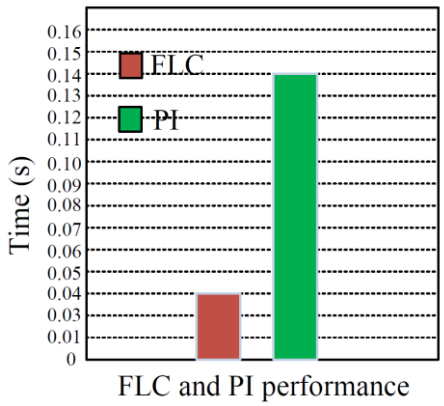


Fig.5. Performance of PI and FLC

The proposed fault has been investigated in shown Fig. 6. When the fault occurs to 2s the voltage becomes zero and abnormal current started at same time. These faults were cleared at 2.1s, the inverter could deliver the normal current to the desire load.

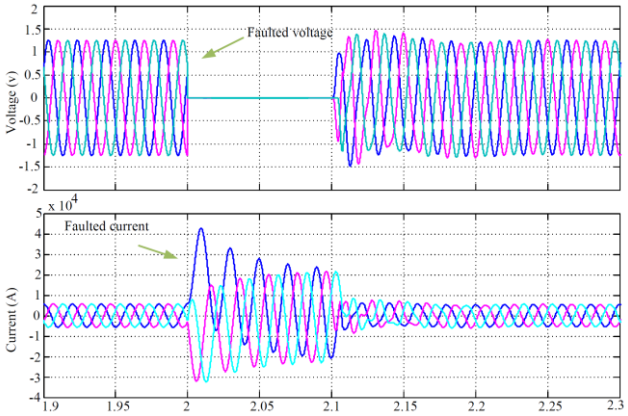


Fig.6.Voltage and current fault for ITER PF converter

V. CONCLUSION

The paper mainly investigated the normal and fault analysis for ITER PF converter system. The FC and PI controller has associated and verified the simulation results. The proposed FC technique in the ITER PF converter is attractive method in modern control engineering. Due to the good performance of the FC has achieved the International Organization (IO) designed requirements.

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