FLC BASED TUNINIG OF PID CONTROLLER FOR AN AUTOMATIC VOLTAGE REGULATOR SYSTEM

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Abstract: In this paper Proportional-Integral-Derivative (PID) controller is designed for an Automatic Voltage Regulator (AVR) system, so that faster settling to rated voltage is ensured and the instability is avoided. A VR is a closed loop control system compensated with a PID eontroller.by using ZN method and Fuzzy Logic Controller. Simulations are done to show the performance of PID controlled A VR system tuned using ZN Method an FLC and the results are compared.

Keyword: PID controller tuning, Ziegler-Nichols tuning and FUZZY Logic Controller and Simulation

I. Introduction

An Automatic Voltage Regulator is a device that is used to regulate the supply line voltage to a level that is safe for the equipment connected to it. A VR is mainly used in areas where the supply voltage is not stable and fluctuation of load occurs. The generator excitation system maintains generator voltage and controls the reactive power flow using an AV R. The AVR system is a closed loop control system compensated with a PID or PSS controller. The Power System Stabilizer (PSS) controller is used for AV R system with high gain thirstier excitation system and has six tuning parameters. The Proportional Integral Derivative (PID) controller is used for AV R system with normal gain exciter and has three controller gains as the tuning parameters. In addition to these two controllers, a Fractional Order PID (FOPID) controller, which is a generalization of standard PID controller, can also be used for the AV R system. FOPID controller has five tuning parameters that include three controller gains, a derivative order and an integral order. Among these three controllers PID controllers are widely used due to its simple structure, easy implementation since it has only three tuning parameters and providing robust performance in wide range of operating conditions. Optimal tuning of PID control parameters are needed for the best performance of the system.

Previously various conventional tuning techniques such as Ziegler/ Nichols tuning, Cohen Coon method, minimum variance method, gain phase margin methods were used. But these methods exhibited some demerits such as extensive mines to set the gains, difficulty to deal with nonlinear systems and complexity of control design. Hence recently many evolutionary algorithms such as Genetic Algorithm (GA), Differential Evolution (DE) algorithm, Artificial Bee Colony (ABC), Chaotic Optimization Algorithm, Chaotic Ant Swarm (CAS) Algorithm and Particle Swarm Optimization (PSO) Algorithm were used for tuning. In 2004, Gain compared the GA with Simulated Annealing and concluded that GA is faster due to its parallel search techniques, but has the disadvantage of premature convergence. Coelho in 2009 proposed that the Chaotic Optimization Aigorithm has the feature of easy implementation, short execution time and robust mechanism of escaping from local optima. The proportional – integral – derivative (PID) controller operates the majority of the control system in the world. It has been reported that more than 95%

of the controllers in the industrial process control applications are of PID type as no other controller match the simplicity, clear functionality, applicability and ease of use offered by the PID controller. The PID controller is used for a wide range of problems like motor drives, automotive, flight control, instrumentation etc. PID controllers provide robust and reliable performance for most systems if the PID parameters are tuned properly. Various tuning methods are explained in. Among the tuning methods, the Ziegler-Nichols (ZN) technique has been very influential. Ziegler-Nichols presented two tuning methods a step response method and a frequency response method. The frequency response method is more reliable than the step response method. The field of Fuzzy control has been making rapid progress in recent years. Fuzzy logic control has been widely exploited for nonlinear, high order & time delay system. This paper has two main contributions. Firstly, a PID controller has been designed for higher order system using Ziegler-Nichols frequency response method and its performance has been observed. The Ziegler Nichols tuned controller parameters are fine tuned to get satisfactory closed loop performance. Secondly, for the same system a fuzzy logic controller has been proposed with simple approach and smaller number of rules (four rules) as it gives the same performance as by the larger rule set Simulation results for a higher order system have been demonstrated. A performance comparison between Ziegler Nichols tuned PID controller, and the proposed fuzzy logic controller is presented. The paper has been explains generalized model of PID controller. Describes the design consideration for a higher order system. Design of PID controller using Z-N technique and design of fuzzy logic controller using simple approach and smaller rule base. Finally conclusion close the paper.

II.AVR SYSTEM MODELING

A simple AVR system comprises four main components, namely amplifier, exciter, generator, and sensor. For mathematical modeling and transfer function of the four components, these components must be linearized, which takes into account the major time constant and ignores the saturation or other nonlinearities. The transfer function model of each component consists of a gain and a time constant and is given as

Transfer function model of an amplifier is TF (a) = Ka/1+STa

Transfer function model of an exciter is: TF (e) = ke/1+STe

Transfer function model of a generator is: TF (g) = Kg/ 1 +S Tg

Transfer function model of a sensor is: TF(s) = Ks/1+STs

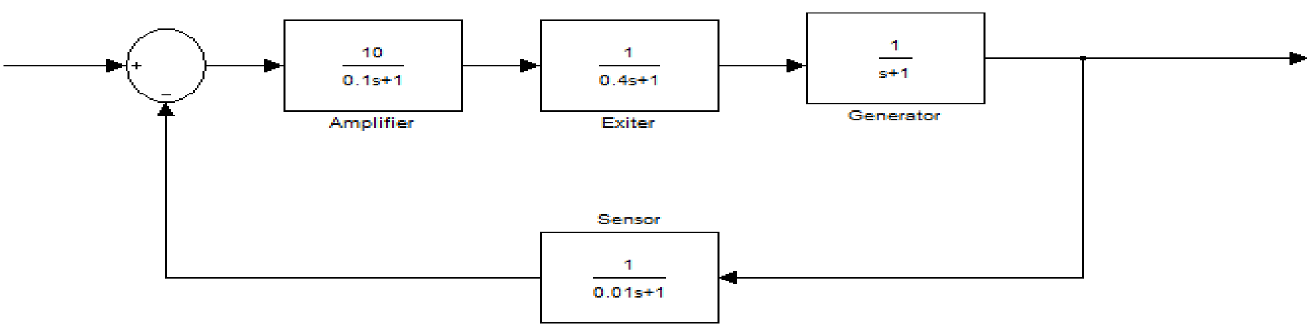


Fig.1 Block diagram of Automatic voltage Regulator system

The typical parameter limits of the gain and time constants of the components and the parameter values used are given in the Table I. Using the mentioned parameter values, the transfer function model of an Automatic Voltage Regulator system is given shows the open loop response of the AV R system and its transfer function

Table I: The parameters limits of AVR System

	Parameter Limit		Parameter Values	
	Gain	Time constant	Gain	Time constant
Amplifier	10.0<ka<40	0.02<Ta<0.1	Ka=10	Ta=0.1
Exciter	1<ke<10	0.4<Te<1.0	Ke=1	Te=0.4
Generator	0.7<kg<1	1.0<Tg <2.0	Kg=1	Tg=1.0
Sensor	Ks=1	0.001<Ts<0.06	Ks=1	Ts=0.01

Transfer function of AVR SYSTEM without any controller is given by

$$\frac{\Delta Vt(s)}{\Delta Vref(s)} = \frac{0.1s + 10}{o.ooo4s4 + 0.0454s + 0.555s2 + 1.51s + 11}$$

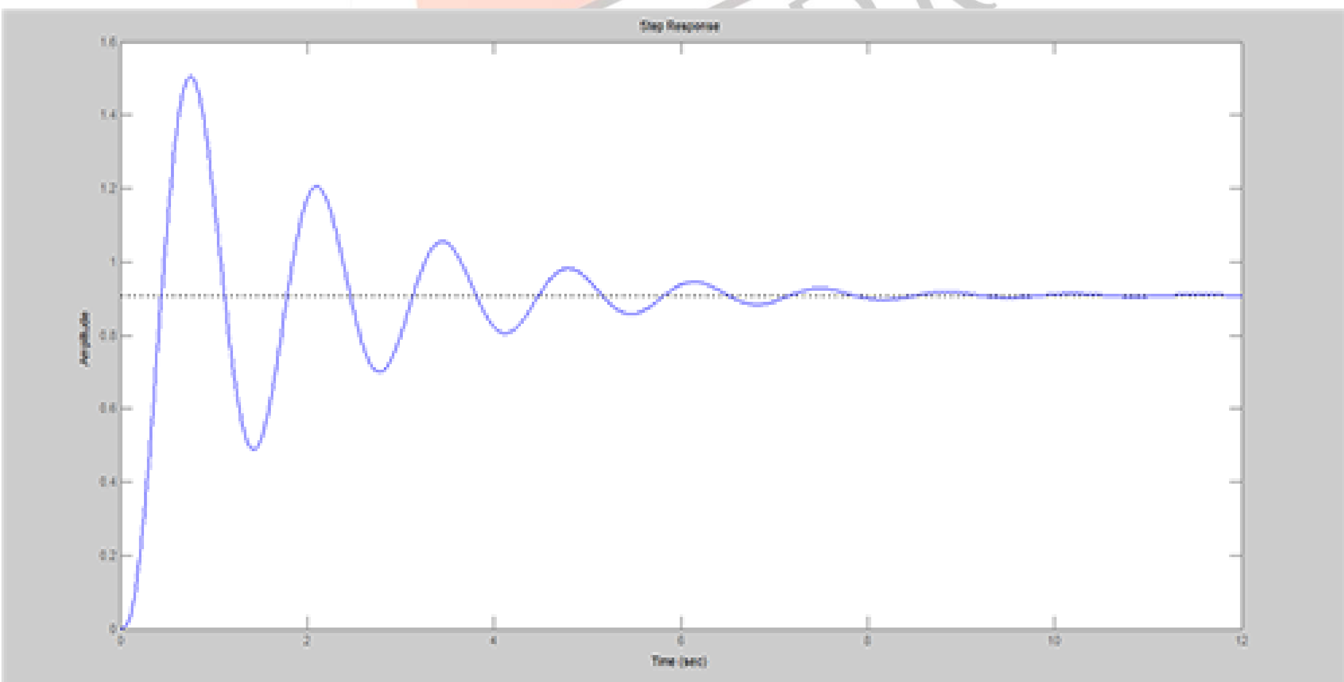


Fig. 2 Response of AVR SYSTEM without PID Controller

III. Zigler-Nichol Method

The ZieglerNichols tuning method is a heuristic method of tuning a PID controller. It was developed by John G. Ziegler and Nathaniel B. Nichols. It is performed by setting the I (integral) and D (derivative) gains to zero. The "P" (proportional) gain, is then increased (from zero) until it reaches the ultimate gain, at which the output of the control loop has stable and consistent oscillations. And the oscillation period are used to set the P, I, and D gains depending on the type of controller Block diagram of AVR SYSTEM with ZN-PID controller and response of AVR SYSTEM with ZN-PID controller.

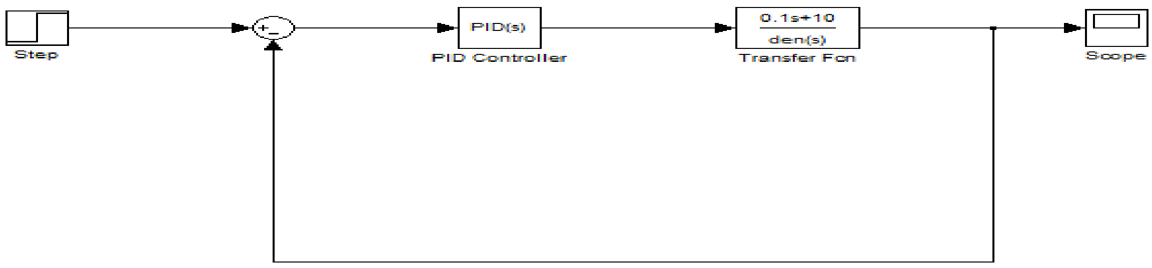


Fig.3 Transfer Function representation

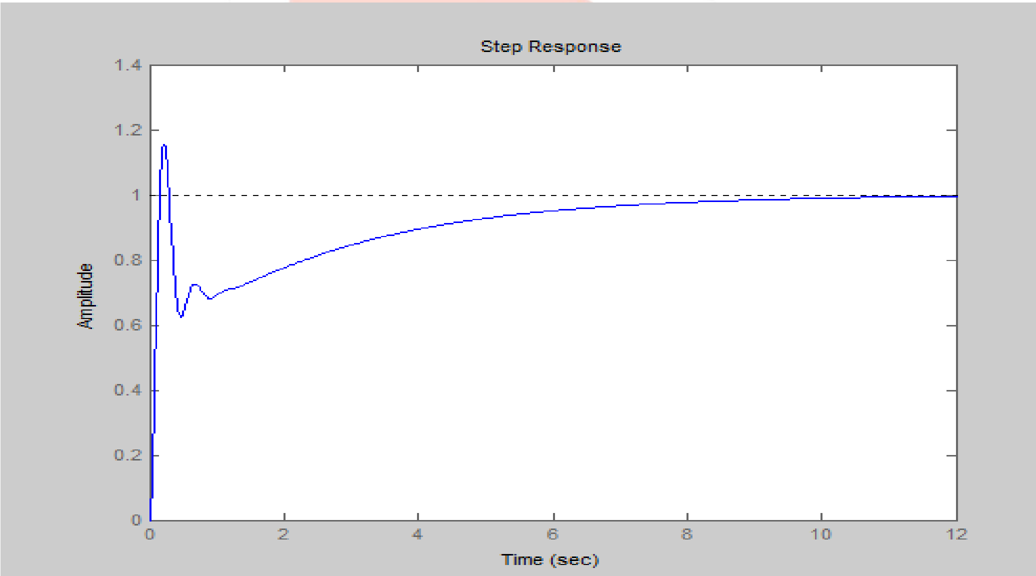
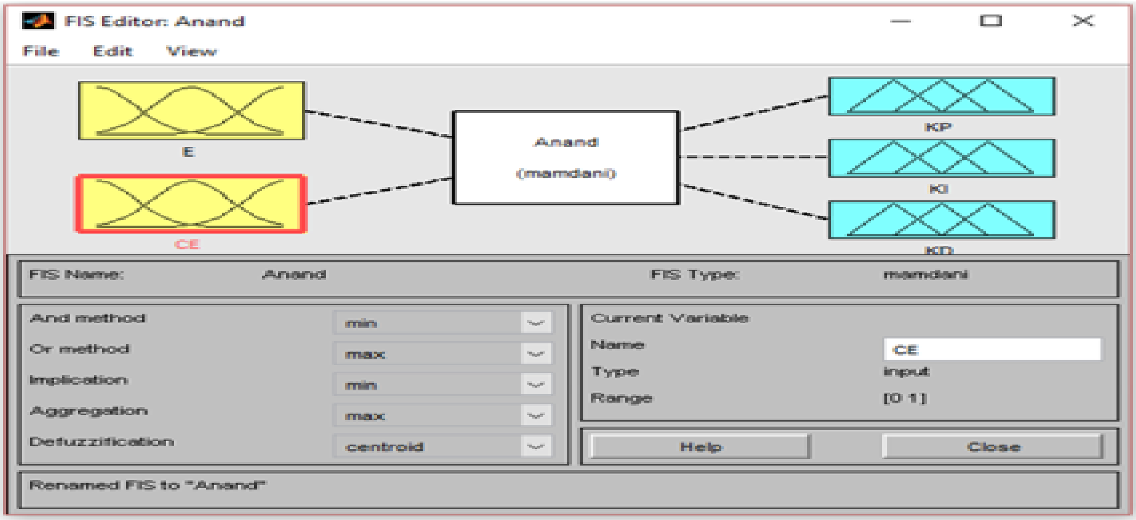


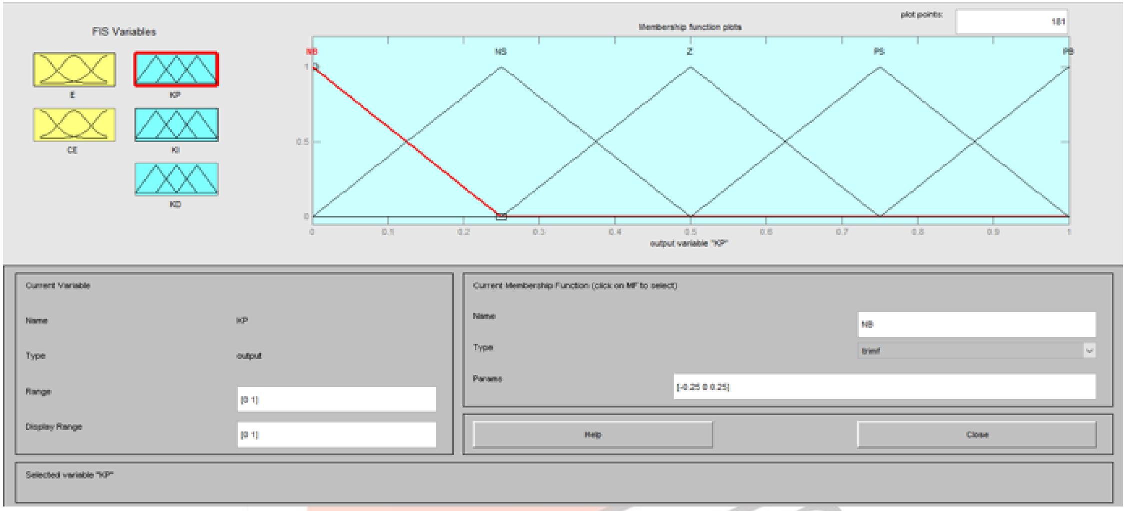
Fig.4 Step Response representation

IV.Design of Fuzzy Logic Controller (Flc)

For a two input fuzzy controller, 3,5,7,9 or 11 membership functions for each input are mostly used [7]. In this paper, only two fuzzy membership functions are used for the two inputs error e and change in error membership functions for the output parameter are show here N means Negative, Z means Zero and P means Positive.

In output membership function NB is negative big, NS is negative small, Z is zero, PS is positive small and PB is positive big.





FUZZY RULES FOR KP

E/CE	N	Z	P
N	NL	Z	PS
Z	NS	Z	PL
P	NL	PL	NL

FUZZY RULES FOR Ki

E/CE	N	Z	P
N	Z	PS	Z
Z	PS	Z	NS
P	NS	PL	NS

FUZZY RULES FOR Kd

E/CE	N	Z	P
N	PS	PS	PS
Z	PS	Z	NS
P	PL	PL	PL

Transfer function of AVR SYSTEM with fuzzy-PID controller is given by

$$TF = \frac{0.0547s3 + 5.5208s2 + 5.1345s + 5.45}{0.0004s5 + 0.045s4 + 0.555s3 + 6.98s2 + 6.08s + 5.45}$$

The response of AVR SYSTEM with fuzzy-PID controller is

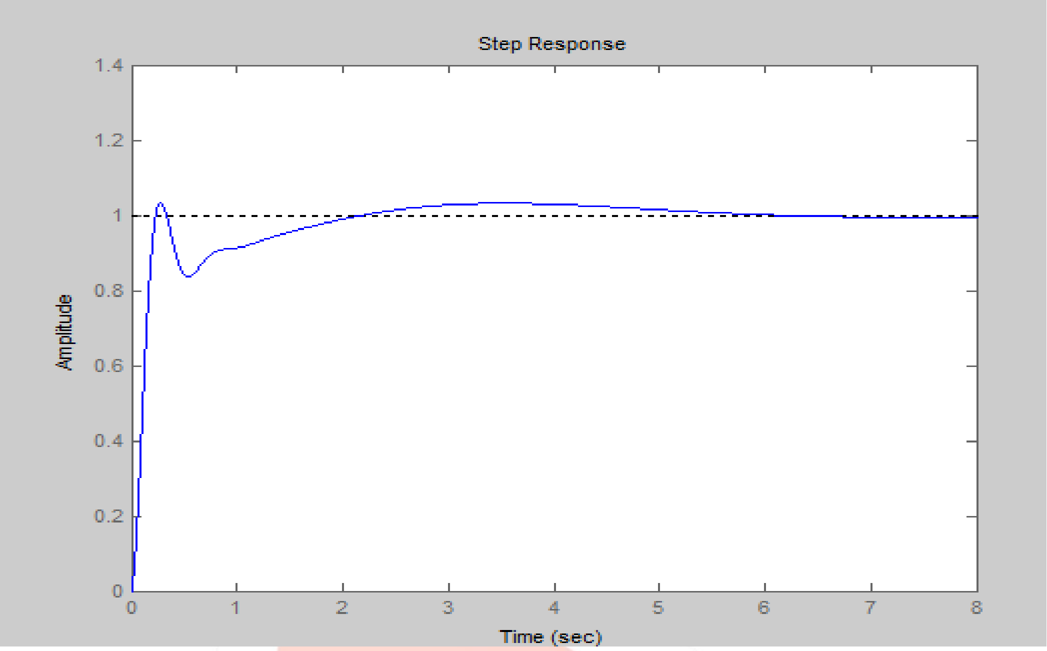


Fig.5 Step Response representation

Time response parameters percent overshoot, settling time and Peak Amplitude for Zeigler Nichols tuned PID controller (ZNPIDC) and FUZZY LOGIC CONTROOLER for AVR SYSTEM is given bellow.

	OVERSHOOT	**SETTILINGTIME**	**PEAK AMPLITDE**
AVR SYSTEM	65.7	6.99	1.51
ZN-PID	15.6	8.4	1.16
FLC	3.26	4.65	1.03

The transfer function of the AVR and ZN –PID AVR and FUZZY PID AVR is given bellow

$$\frac{\Delta Vt(s)}{\Delta Vref(s)} = \frac{(0.1s + 10)}{(0.0004s^4 + 0.0454s^3 + 0.555s^2 + 1.51s + 11)}$$

$$\frac{(0.81414s^3 + 8.594s^2 + 18.0962S + 9.62)}{\frac{\Delta Vt(s)}{\Delta Vref(s)} = (0.0004s^5 + 0.0454s^4 + 0.555s^3 + 9.924s^2 + 19s + 9.62)}$$

$$\frac{\Delta Vt(s)}{\Delta Vref(s)} = \frac{(0.0547s^3 + 5.5208s^2 + 5.1345S + 5.45)}{(0.0004s^5 + 0.0454s^4 + 0.555s^3 + 6.98s^2 + 6.08s + 5.45)}$$

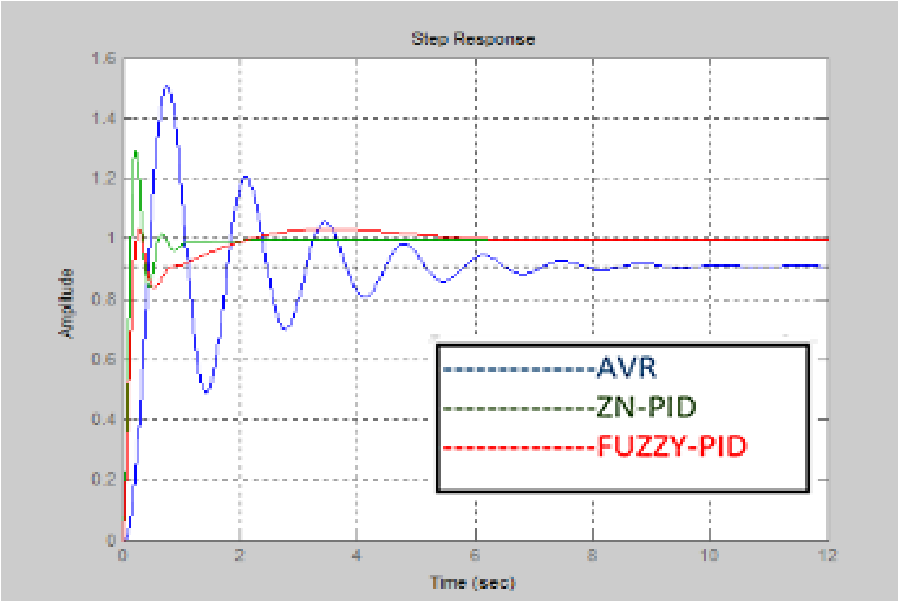


Fig.6 Step Response representation of AVR, ZN-PID, FUZZY-PID

V.CONCLUSION

This paper presented an overview of PID controller, design of PID controller using Z-N technique and design of fuzzy logic controller for AUTOMATIC VOLTAGE REGULATOR system. Simulation results using MATLAB / SIMULINK are discussed for Ziegler Nichols tuned PID controller and the Fuzzy logic controller. Ziegler Nichols technique gives high overshoot and settling time. Initial controller parameters obtained using Z-N formula need to be adjusted repeatedly through computer simulation to get satisfactory performance. Fuzzy logic controller gives smaller overshoot and settling time than Ziegler Nichols tuned PID controller. The Fuzzy Logic controller gives less overshoot and smaller settling time than obtained using Ziegler Nichols tuned PID controller and automatic voltage regulator system without any controller. The simulation results confirms that the proposed Fuzzy logic controller with simple design approach and smaller rule base can provide better performance comparing with the Ziegler Nichols tuned PID controller.

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