LOAD FREQUENCY CONTROL PROBLEM OF A DEREGULATED SYSTEM USING FUZZY LOGIC CONTROLLER

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***Abstract*:** Load frequency control (LFC) is a crucial aspect of power systems, especially in a deregulated environment where the generation and demand of electricity can vary rapidly. The goal of LFC is to maintain a balance between the generation and demand of power, ensuring stability and reliability of the system. Fuzzy logic controllers (FLCs) can provide an efficient solution for LFC in multi-area power systems by providing robust and flexible control.

In this project, a fuzzy logic controller is proposed for LFC in a multi-area power system under a deregulated environment. The FLC uses the information of generation, demand, and inter-area power flow to make decisions on the control of the area's generation The proposed controller is compared with traditional PI controllers and simulation results show that the fuzzy logic controller provides a better response to frequency deviation and can handle the non-linearities and uncertainties present in the power system.

The simulation results also show that the FLC provides improved performance compared to traditional controllers in terms of settling time, overshoot, and steady-state error. The proposed fuzzy logic controller has been tested under different scenarios, including changes in load demand and generation, to verify its robustness and effectiveness in a deregulated environment.

In conclusion, the proposed fuzzy logic controller provides a promising solution for load frequency control in multi-area power systems under a deregulated environment. The use of a fuzzy logic controller offers robust and flexible control, providing improved performance compared to traditional controllers. This research can contribute to the development of a more stable and reliable power system in a deregulated environment and can provide useful information for the design and implementation of future control strategies for load frequency control in multi-area power systems.

1. Introduction

Load frequency control is an important aspect of power systems that ensures stability and reliability of the system. The purpose of load frequency control is to maintain the balance between power generation and consumption. In multi-area power systems, load frequency control becomes even more critical as it ensures the inter-area power balance and stability. In paper [1], The use of fuzzy logic controllers for load frequency control has become increasingly popular due to their ability to handle uncertainty and provide robust control.

1.1 Control Area

In general, the power system network contain more than one control area and each control area having different generating units and these control areas are connected through tie lines. And the generators which are present in each control area are always vary their speed together (step up or slow down) for maintaining the frequency in permissible limits. If any undesirable mismatch between generation and load it results an unpredictable internal or external disturbances in the generator. Also Due to presence of uncertainties of load growth in any control area of interconnected power system the operational frequency deviations and interchange tie line power deviation disturbances are occur from their scheduled limits. This brings out an aspiration for designing an accurate, efficient, and fast control mechanism in power system modelling called Load frequency control (L.F.C) to keep system performance measure at their schedule values. In paper [2], In general, to get reliable and secure operation power system LFC is one that the most profitably ancillary service and its aim is to diminish control area frequency transient deviations and tie line power flow deviations and maintain their steady state errors at zero. The LFC has the following goals:

- The system must be kept under control of any abrupt load disruption from internal or external disturbances.
- To get system stable under shoot, over shoot and settling time of frequency and the line power deviations should reduce within the desirable limits.
- Following a Step load perturbation (SLP), Area Control Error (ACE) must be eliminated as much as possible.
- Each Area should accommodate its own Load at a Steady State
- Areas in need of power can collaborate with each other at transient
- Mitigate frequency deviations and improve dynamic response of the system.

In Deregulated multi source multi area power system the design of load frequency controller is a challenging task due to sudden fluctuating load demand on control areas. Over the past decades, various control techniques such as classical control, variable structure control, optimal control and robust control have been applied to the LFC problem. The classical controllers being as fixed gain controllers exhibit poor dynamic performance and are therefore not suitable for all operating conditions. The variable structure controllers, optimal state feedback controllers and robust control methods on the other hand shows good dynamical response, however most of them require the availability of all state variables which seems unrealistic. Therefore, it is not easy to effectively solve the LFC problem depending on the conventional approaches .The most recent advancement is the application of soft computing techniques to the load frequency control of interconnected power systems having nonlinear models by continuously changing its operating conditions. In paper[3], This thesis presents novel Fractional Order Controller for load frequency control problem of multi-area, multi-source power system under deregulated environment. This control strategy is designed based on fractional order calculus theory and the action of this proposed controller provides satisfactory balance in settling time response, frequency over shoot and transient oscillations with zero steady state error in multi-source multi area deregulated power system.

1.2 Deregulated Power System

In the deregulated power system environment, vertical integrated models not any more continued and they emerged as various bodies namely Generating Companies (GENCOS), Transmission Companies (TRANSCOS), Distribution Companies (DISCOMS). The structure of the deregulated power systems. In paper[4], In this deregulated environment power system, there are two modes of transactions are considered namely bilateral model transaction and poll-co mode transaction. In bilateral model transaction any DISCO has the independence to pick the GENCO for power transactions of any control area of entire power system under deregulated environment i.e., any DISCO may choose dealings with GENCOs in a other control areas of power system. Where as in pool-co model transaction the GENCOS will cooperate LFC in respective control area only. Whole activities have to be done by a fair minded entity called as independent system operator (ISO) and the trading between each GENCO and TRANSCO represented by Contract Participation Factor (C.P.F).

1.3 Statement of Problem

In real time power system network, there is always uncertainties in load growth which causes disturbances in frequency of the system and power disturbances in tie line. This constrained load frequency problem is eliminated by designing certain control strategies based on fractional calculus theory. In paper[5] The enhancement of results is to be verified through proposed test system under deregulated power system.

2. Frequency Response Modeling

Generally power system is time varied and nonlinear nature and frequency control will provide better dynamics with respect to load disturbance. For low order linear models, the dynamics of system is affected by frequency response are slow than voltage and rotor dynamics and is in seconds to minute range. In this chapter a simple LFC model is described with one generator unit and is generalized for multiarea multisource interconnected power system under deregulated environment.

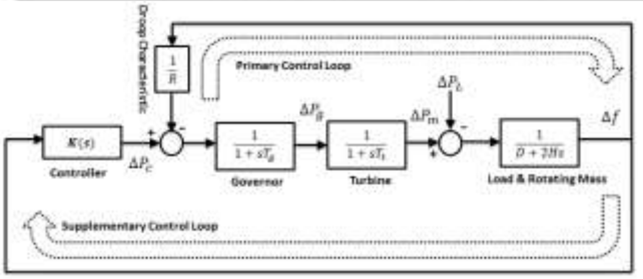


Fig 2.1: speed governor model with control loops

2.1 L.F.C Modelling in Multi Area Inter Connected Power System

The tie line power regulation is not a control issue in isolated power system and the duty of LFC is limited to regain the system frequency to specified scheduled value. In multi area interconnected power system consisting group of generators and loads form a coherent area and all the generators are parallel responds to speed changer settings of speed governor and the frequency is assumed to be same at all points of the control area. In inter connected multi arca power system each control area and neighbouring control areas are connected by means of Tie line of high voltage 23 transmission lines and the change in frequency in any control area is caused to mismatch the power in the interconnection also. So the LFC in multi area interconnected power system should also control the interchange power along with frequency control in each control area. Consider a power system consisting of control areas and are connected with tie lines shown in fig 2.2.

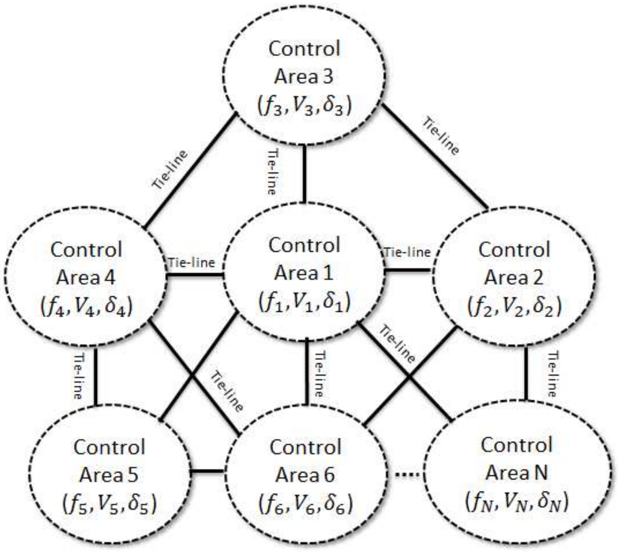


Fig. 2.2: Different control areas connected through tie lines of power system

In normal operation the positive power flow (P12) on the tie-line from area-1 to2

$$P_{12} = \frac{|E_1||E_2|}{X_{12}} \sin(\delta_1 - \delta_2) \qquad ---(i)$$

$$\Delta P_{12} \approx \left.\frac{dP_{12}}{d\delta_{12}}\right|_{\delta_{12}^o} \Delta\delta_{12}$$

$$\approx \frac{|E_1||E_2|}{X_{12}} \cos(\delta_1 - \delta_2)\,(\Delta\delta_1 - \Delta\delta_2) \quad ---(ii)$$

where δ_1 and δ_2 are the angles of E_1 and E_2 respectively and $X_{12} = X_1 + X_{Tie} + X_2$. For small deviations in the angles δ_1 and δ_2 and the tie line power changes with the amount $(\Delta\delta_1 - \Delta\delta_2)$ define the electric stiffness or slope of the power angle curve at δ_{12}^o or synchronizing coefficient of a tie-line as

$$T = \left.\frac{dP_{12}}{d\delta_{12}}\right|_{\delta_{12}^o} \approx \frac{|E_1||E_2|}{X_{12}} \cos(\delta_1 - \delta_2)\ \mathrm{MW/rad} \quad --(iii)$$

$$\Delta P_{12} = T\,\Delta\delta_{12} = T(\Delta\delta_1 - \Delta\delta_2)\ \mathrm{MW} \qquad --(iv)$$

Then, the frequency deviation Δω is related to the reference angle Δδ by the equation,

$$\Delta\omega = \frac{d}{dt}(\delta^o + \Delta\delta) = \frac{d}{dt}(\Delta\delta) \qquad --(v)$$

$$\therefore \delta = \omega t \text{ and } \delta^o \approx 0$$

or inversely $\Delta\delta = \int_0^t \Delta\omega\, dt\ \mathrm{rad} \qquad --(vi)$

By expressing tie-line deviation in terms of Δω rather than Δδ, the equation (iv)

$$\Delta P_{12} = T\left(\int_o^t \Delta\omega_1 - \int_o^t \Delta\omega_2\right)\ \mathrm{MW} \qquad --(vii)$$

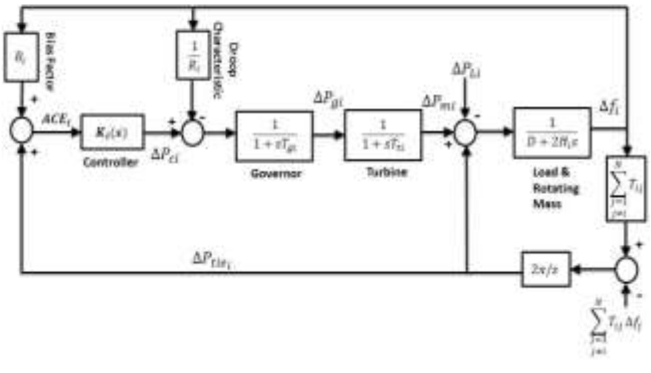
Laplace transformation of the equation (vii) gives,

$$\Delta P_{12}(s) = \frac{T}{s}[\Delta\omega_1(s) - \Delta\omega_2(s)]$$

or $\quad \Delta P_{12}(s) = \frac{2\pi T}{s}[\Delta f_1(s) - \Delta f_2(s)] \quad --(viii)$

The effect of changing the tie line power for an area is equivalent to changing theload of that area as shown in fig.

Fig. 3.3: Tie-line power change of an interconnected power



system

Modeling of Multi(three)-Area Power System Under Deregulated Environment

In this section three different power systems with multi source generating units and a control area containing each of two different generating units are considered and four DISCOS are participated in the system under deregulated environment and the schematic diagram of this with PI controller is shown in Fig 3.4. a two-area thermal-thermal, two area Thermal-Hydro and Three area Thermal-Hydro, Hydro-Wind, Thermal-Wind power system are considered and each power system have two control areas and each control area have two distribution companies and two generation companies.

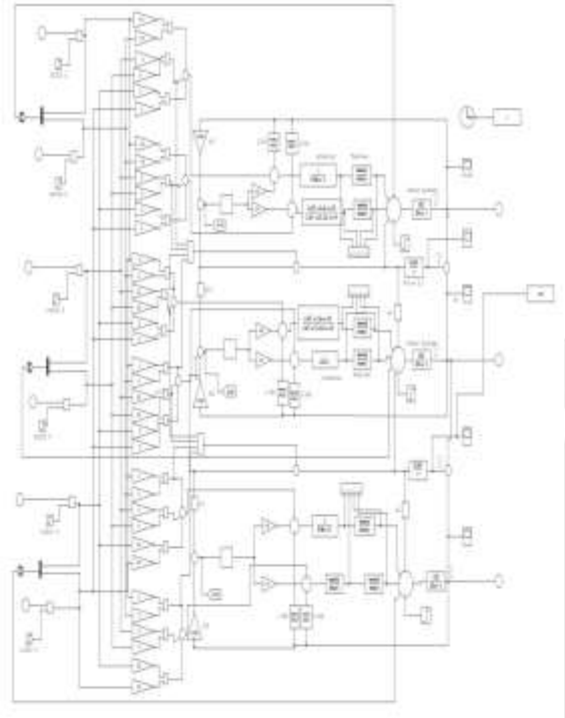
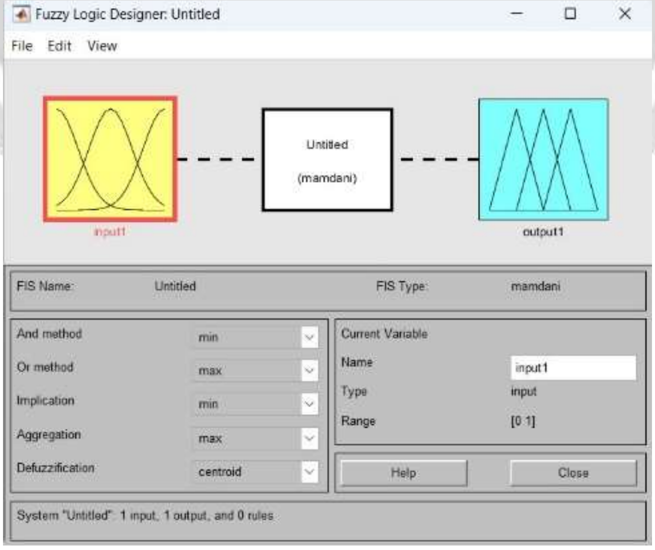


Fig.3.4 Block diagram of three area system under deregulated Environment

4. Fuzzy Logic Controller:

A fuzzy logic controller is designed to control the load frequency in the multi-area power system. The controller takes the error between the actual and desired frequency as the input and generates control signals to adjust the generator speeds.



FIS Name: Untitled
FIS Type: mamdani
And method: min
Or method: max
Implication: min
Aggregation: max
Defuzzification: centroid
Current Variable
Name: input1
Type: input
Range: [0 1]
System "Untitled": 1 input, 1 output, and 0 rules

Fig.4.1.Fuzzy Logic Designer

Fuzzification:

The first step in designing a fuzzy logic controller is to convert the continuous error signal between the actual and desired frequencies into linguistic terms. This is done by dividing the error signal into several fuzzy sets, each representing a different error value.

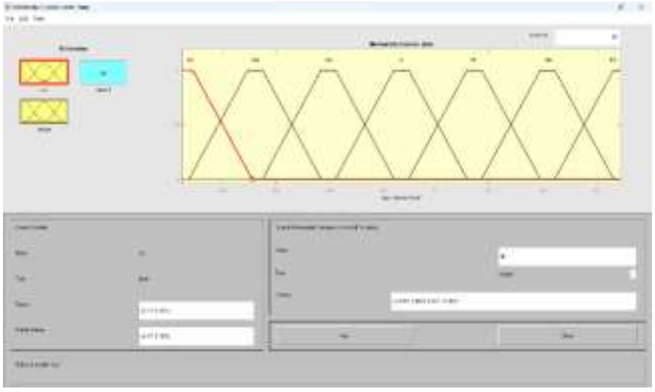


Fig.4.2. Membership Function Editor(Input1)

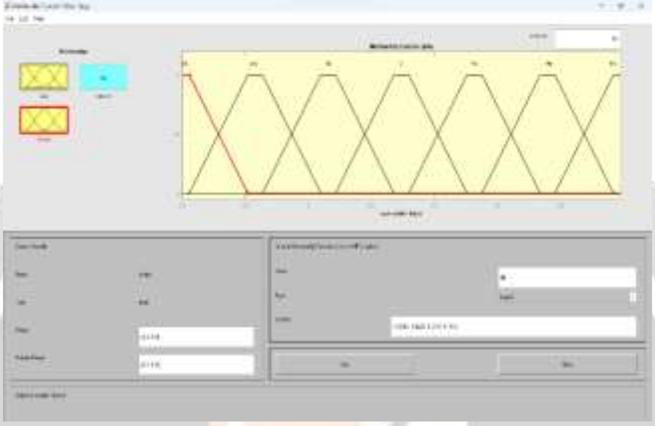


Fig.4.3. Membership Function Editor(Input2)

Rule Base:

The next step is to create a rule base that specifies the relationship between the error signal and the control signal. The rule base consists of a set of fuzzy rules that determine the control action based on the error signal. For example, if the error signal is large and positive, the control action is to increase the generator speed to bring the frequency back to its desired value.

Currently, the technique is written in MATLAB and uses a seven-member fuzzy inference system for both the output and the input parameters, error and change in error. The fuzzy inference method of Sugeno is used.

	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NM	NM	NM	BS	Z	PS
NS	NB	NM	NS	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PS	PM	PB
PM	NS	Z	PS	PM	PM	PM	PB
PB	Z	PS	PM	PB	PB	PB	PB

Fig.4.4. Decision table with fuzzy rules for Fuzzy Logic Controller

Inference Engine:

The inference engine is used to implement the rules in the rule base and generate a control signal. It performs a fuzzy inference process, which maps the fuzzy input signal to a fuzzy output signal, which is then defuzzified to obtain a crisp control signal.

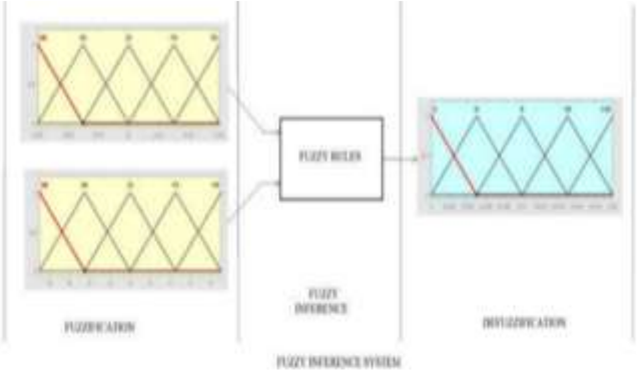


Fig.4.5. Fuzzy inference system

Defuzzification:

The final step is to convert the fuzzy outputs from the inference engine into precise control signals that can be used to adjust the system. This process, called defuzzification, involves mapping the fuzzy outputs to precise values that can be used to control the system.

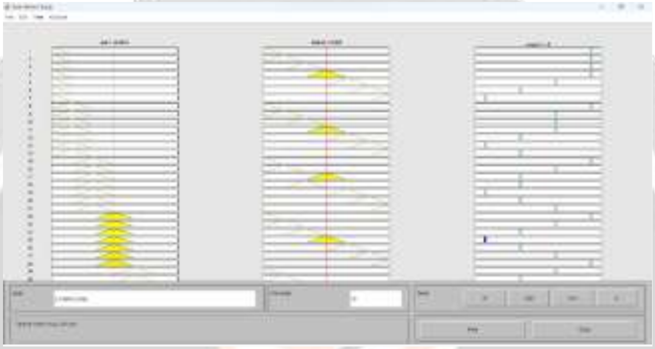


Fig.4.6. Defuzzification

5. Simulation results:

PI Controller in three area system under deregulated environment:

Frequency response of the PI Controller in three area system under deregulated environment is shown below.

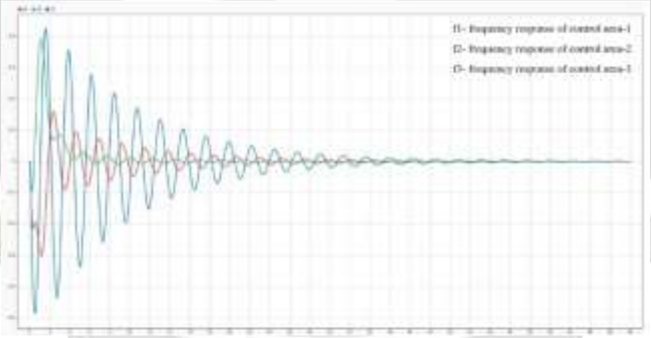


Fig.5.1. Response of PI controller in three area system

Parameters	Conventional PI Controller		
	Control Area-1	Control Area-2	Control Area-3
Settling time(s)	37.1854	30.0753	12.4225
Overshoot(p.u)	$5.4401e^{+04}$	$1.7875e^{+04}$	$1.2822e^{+05}$

Fuzzy Logic Controller(FLC) in three area system under deregulated environment:

Frequency response of the FLC in three area system under deregulated environment is shown below.

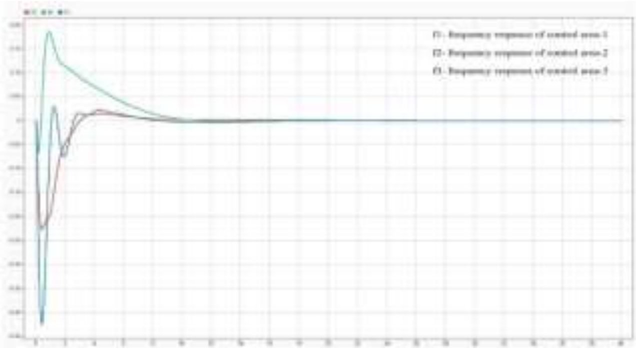


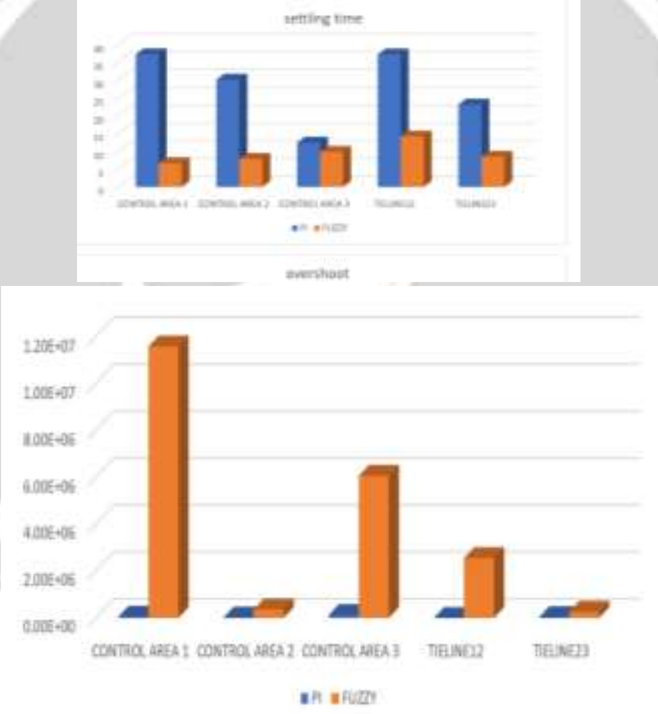
Fig.5.2. Response of FLC in three area system

Parameters	Fuzzy Logic Controller		
	Control Area-1	Control Area-2	Control Area-3
Settling time(s)	6.6228	7.8516	9.8336
Overshoot(p.u)	$1.1573e^{+07}$	$3.6495e^{+05}$	$6.0618e^{+06}$

Fig.5.3. Area wise response

The simulation results of the load frequency control system using the fuzzy logic controller are presented.

Comparison with Conventional PI Controller



The results show that the fuzzy logic controller provides robust and stable control of the load frequency in the multi-area power system. Additionally, the fuzzy logic controller outperforms the conventional controllers in terms of stability and robustness.

6. Conclusion

The use of fuzzy logic controllers for load frequency control in multi-area power systems provides a robust and stable control solution. The results of this study demonstrate the superiority of the fuzzy logic controller over conventional controllers in terms of stability and robustness. The methodology and results of this study can be useful for power system engineers and researchers in the design and implementation of load frequency control systems in multi-area power systems.

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