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Active and Reactive Power Control of Three Phase Grid Connected System with Proportional-Resonant Controller by using SVPWM Technique

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Abstract;- **This paper presents detailed analysis of operation and design of Proportional resonant (PR) controller by using SVPWM technique. On the basis of LCL filter, double-loop current control scheme with the proportional-resonant method is simulated. The proposed control method can reduce the steady-state error of the current, and eliminate the impact of the grid frequency offset on the net current, and the system oscillation caused by the resonance frequency can be decreased, too. Therefore, the stability and robustness of the grid-connected system are improved Under Unbalanced conditions Active and Reactive power are controlled and regulated by current –loop on stationary reference frame by using PR controller along SVPWM, and results are used to provide a comparison between the different control strategies. The analysis is performed on a traditional three-phase voltage source inverter, used as a simple and comprehensive reference frame. Among the conclusions are the feasibility and great potential of PR particularly for power systems with a reduced number of switching states. In addition, the possibility to address different or additional control objectives easily in a single cost function enables a simple, flexible, and improved performance controller for power-conversion .The operation and performance parameters are compared for two models under unbalanced conditions. The study was done by simulating the system on Mat lab for 3KW grid connected system .Finally, both simulation and experimental results are presented in conclusion.**

***Keywords*— Converters, LCL Filters, resonant controller; VSC converters; SVPWM technique**

I. INTRODUCTION

In recent years the utilization of renewable energy sources for electrical power generation was increased rapidly. For example, renewable energies like wind, hydro, solar, PV cell. Because this are eco-friendly in nature, And this are used in various applications in recent years. The numbers of these systems connected to the grid are increasing. So it is important to regulate the grid Active and Reactive powers and voltages under unbalanced conditions along with in the system frequency range and harmonics are limited under desired range of Grid operation. It increases the grid stability of operation. When all this power sources are integrated to grid system then they produce a power quality (PQ) issues. According to IEEE9829 and IEEE1547 we have to control the power quality in desired range. These standards are achieved by means of robust control schemes. In recent years there are so many techniques are available to control power quality. In those mostly used method is Proportional integral (PI), because of its simplicity of operation and easy of control. However, it has some draw backs PI controller cannot achieve those are instability to track sinusoidal reference frame in single phase system without a steady state error and poor capability of rejecting disturbances due to integral action. These drawbacks can be achieved by Proportional Resonant (PR) controller. It can track sinusoidal reference single phase signals and reject the disturbances within the system. At fundamental frequency PR controller produce an infinite gain;

This paper deals with the problems of system under Dynamic power change conditions. For, this a modified proportional resonant controller (PR) by using SVPEM is applied to control the grid side converter. The design method of controller and filter along with mathematical equations are presented, and a comparison of system voltages under unbalanced condition is done with proportional resonant controller. The simulation results are presented given for both the cases along desired output voltage wave forms in both the cases.

II. SYSTEM MODEL

The three phase voltage source converter
Connected to grid transformer through controller and low pass filter is shown in fig1.

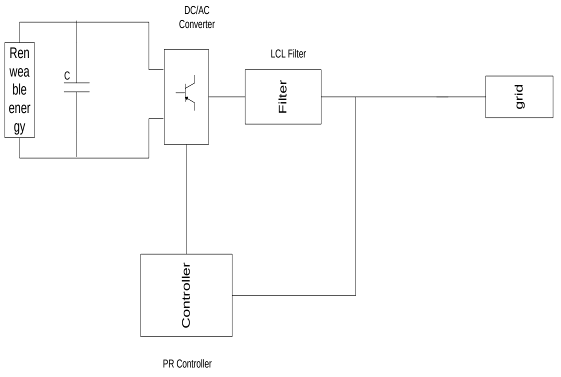

Fig1.System block diagram

This method is mainly concern on grid side converter control. For system simulation we assume input any renewable energy source (PV, Wind, solar energies) as a fixed input voltage source. Here grid side impedance is represented as L_g is connected in series with LCL filter.

Therefore For any change in grid impedance L_g will cause the change of filter resonant frequency

$$W_{\mathrm{Res}} = \sqrt{\frac{L_i + L_g}{L_i L_g C_f}} \qquad (1)$$

Where L_i =inverter side impedance; L_g = grid side impedance; C_f = Filter capacitance

From equation (1) $L_g = \frac{L_i - W_{\mathrm{Res}} L_i L_g C_f}{W_{\mathrm{Res}} L_i C_f}$ (2)

The closed loop block diagram of above system can be represented as shown in below fig.2

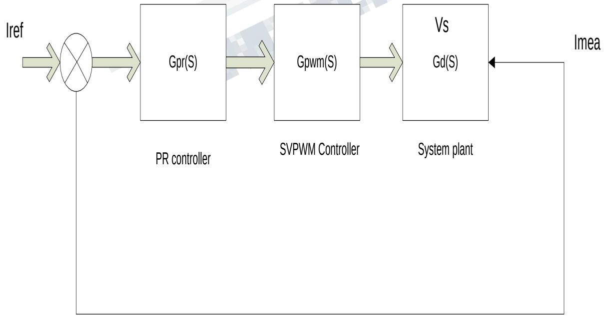

Fig.2 Current control system of PR controller

Forward loop gain is given as

Forward loop gain = $G_{PR}(S).G_{PWM}(S).G_D(S)$ (3)

Where $G_{PR}(S)$, is Proportional Resonant control gain; $G_{PWM}(S)$, is Pulse Width Modulation control gain; $G_D(S)$, is Plant model gain.

The transfer functions of $G_{PR}(S)$,$G_{PWM}(S)$ and $G_D(S)$ are given as

$$G_{PR}(s) = K_P + \frac{2K_i S}{S^2 + W_0^2} \qquad (4)$$

$$G_{PWM} = \frac{1}{1 + 1.5T_S S} \qquad (5)$$

$$G_D(S) = \frac{(S^2 + R_D Z_{LC}^2 S + Z_{LC}^2)}{LS(S^2 + R_D C_F W_{RES}^2 + W_{RES}^2)} \qquad (6)$$

Where T_s is Sampling Period, R_D is filter damping resistance; $Z_{LC}^2 = [L_G + C_F]^{-1}$; $L_{GT} = L_G$

III. BASIC SYSTEM COMPONENTS DESIGN

1. LCL FILTER

In this section we discuss about design and analysis of low pass filter for grid connected inverter. In case of high voltage applications the dynamic response of the L filter is poor. So here we considered LCL filter. It is utilized to limit the harmonics and that gives the improved output voltages and currents. The LCL filters as shown in fig3.

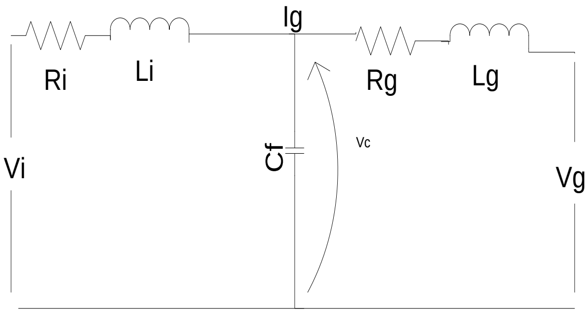

Fig.3 LCL filter without Rd

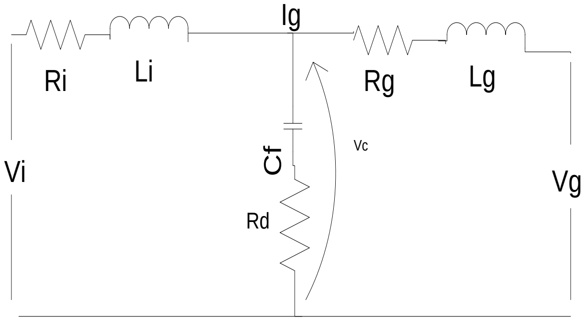

Fig.4 LCL filter with Rd

The transfer equation of LCL filter was obtained by applying Kirchhoff's laws to above fig3.

$$I_i(SL_{fi} + R_{fi} + {}^{1}\!/_{SC_f}) - I_g({}^{1}\!/_{SC_f}) = V_i \qquad (7)$$

$$I_g(SL_{fg} + R_{fg} + {}^{1}\!/_{SC_f}) = 0 \qquad (8)$$

The transfer function is given as

$$H(S) = \frac{I_g}{V_i} \qquad (9)$$

The closed loop transfer function of LCL filter is obtained by utilizing above equation is

$$H(S) = \frac{1}{S^3 L_f L_g C_f + S(L_f + L_g)} \qquad (10)$$

If impedance of the inductance becomes equal to zero then there is a resonance frequency occurs that is given as

$$F_{\text{Res}} = \sqrt{\frac{L_{Fi} + L_{Fg}}{L_{fi} L_{Fg} C_f}} \qquad (11)$$

In order to avoid resonance Effect and to improve the stability of the voltage and currents control a damping resistance is introduced

$$R_d = {}^{1}\!/_{6.W_{\text{Res}} \prod .C} \qquad (12)$$

Now, the transfer function of system with Rd is given as

$$H(S) = \frac{SC_f R_D + 1}{S^3 L_f L_g C_f + S^2 C_f R_d (L_g + L_f) + S(L_f + L_g)} \qquad (13)$$

LCL filter response with out and with R_D are as shown in fig4, fig5,

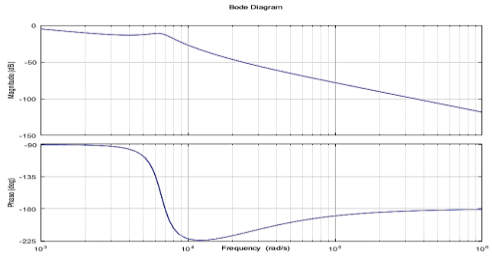

Fig.5 LCL filter without Rd

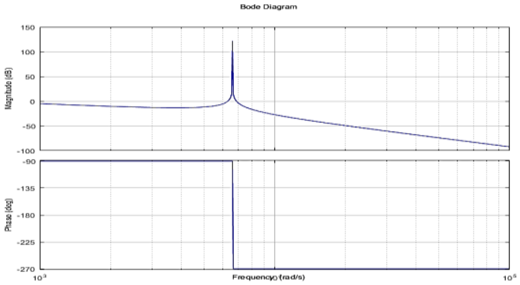

Fig.6 LCL filter with Rd

Proportional resonant (PR) Current Controller Design

PR controller are necessary to work in the stationary reference frame .In this case, PI controller cannot be used because it is not able to track a sinusoidal reference without give any error.

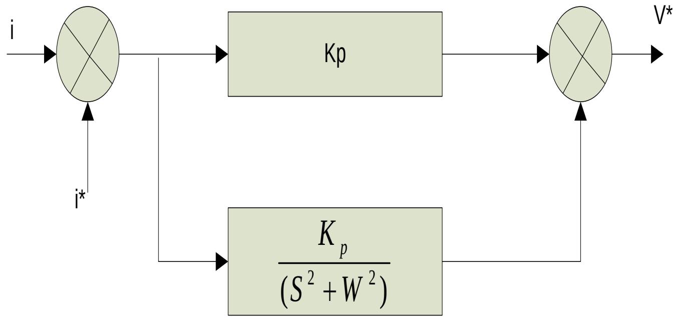

Fig.7 PR controller Block Diagram

The transfer function is given as

$$G_{PR}(S)=K_P+\frac{2K_R S}{S^2+W_0^2} \qquad (14)$$

Where K_P, K_R is proportional and resonance control gains respectively. Comparable to PI controller K_R is responsible to eliminate steady state error. Where K_P is for good transient response and stability grantee.

Equation (15) represents an ideal PR controller which can give stability problems because of infinite gain. To avoid these problems, the PR controller can be made non-ideal by introducing damping as

$$G_{PR}(S)=K_P+\frac{2K_R W_C S}{S^2+2W_C S+W_0^2} \qquad (15)$$

Where W_C is 20% of W_0

The gain is very high; the harmonic compensation can be implemented much easier by using PR controller. The function transfer function for 3rd, 5th, 7thharmonic is

$$G_{Hc}(S)=\sum_{h=3,5,7} K_H \frac{S}{S^2+(hW_0)^2} \qquad (16)$$

The Bode plots of resonant controller for different values of Gain K_i and W_0 are shown in fig.7, fig.8, fig.9

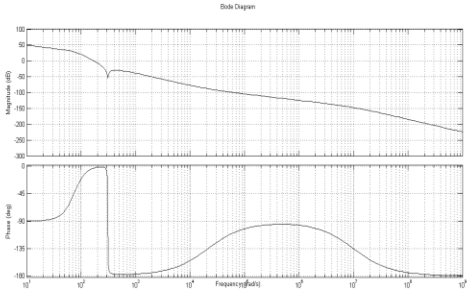

Fig.8 Open loop Bode plot of PR controller

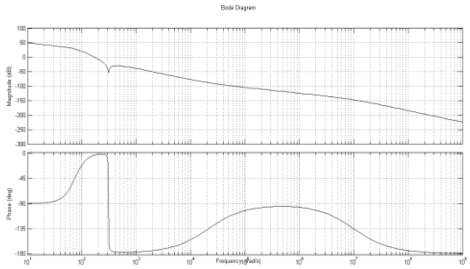

Fig.9 Closed loop Bode plot of PR controller

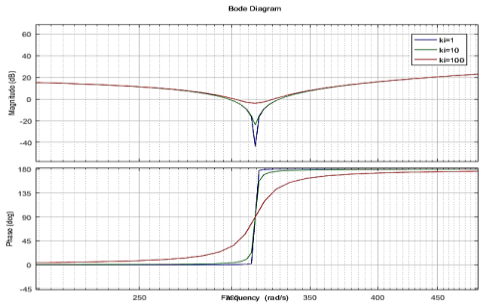

Fig.10 For various K_i values PR controller Response

In practical application, the infinite gain associated with the ideal case might lead to instability problems. Alternatively; non ideal PR controller is applied to improve the performance of the controlled system: When *G*(*s*) is quasi proportional-resonant controller

$$G(S)=K_P+\frac{2W_C K_R S}{S^2+2W_c S+W_h^2} \qquad (17)$$

In, W_C is the cutoff frequency which is introduced to add more flexibility for selecting the bandwidth of the controller and to reduce the sensitivity towards the variation of background grid frequency. Above Fig.4 shows the comparison between the frequency responses of an ideal and non- ideal PR controller. At the fundamental frequency, a high gain is achieved to eliminate the steady state error whereas approximately no gains appear at other frequencies. Quasi proportional-resonant controller not only can maintain high gain at the fundamental frequency, but also reduce the impact of grid frequency offset on the net current. According to the compensation principle, *ugrid* feed-forward control is increased which can completely eliminate the effects of the frequency offset.

SVPWM Technique

There are different types of PWM techniques available those are Sine PWM, Hysteresis, and Space vector PWM. In this we are using SVPWM technique.

Basic Operation

In this it treats the sinusoidal voltage as a constant amplitude vector rotating at constant frequency. This PWM technique approximates the reference voltage V_{ref}

by a combination of the eight switching patterns (V_0 to V_7). Coordinate Transformation (abc reference frame to the stationary d-q frame), A three-phase voltage vector is transformed into a vector in the stationary d-q coordinate frame which represents the spatial vector sum of the three-phase voltage. The vectors (V_1 to V_6) divide

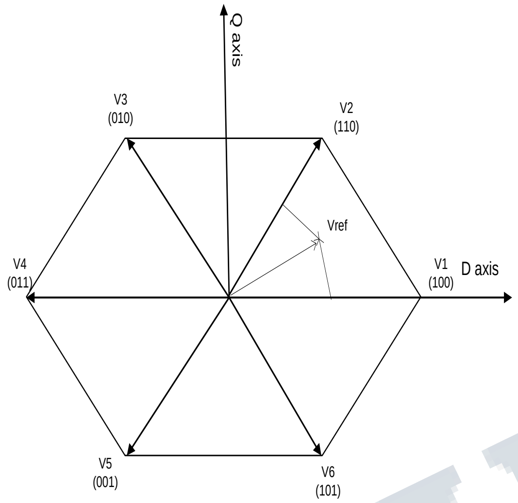

Fig.11 Basic switching vectors and sectors

The plane into six sectors (each sector: 60. degrees V_{ref} is generated by two adjacent non-zero vectors and two zero vectors).

The eight inverter voltage switching outputs are as shown below

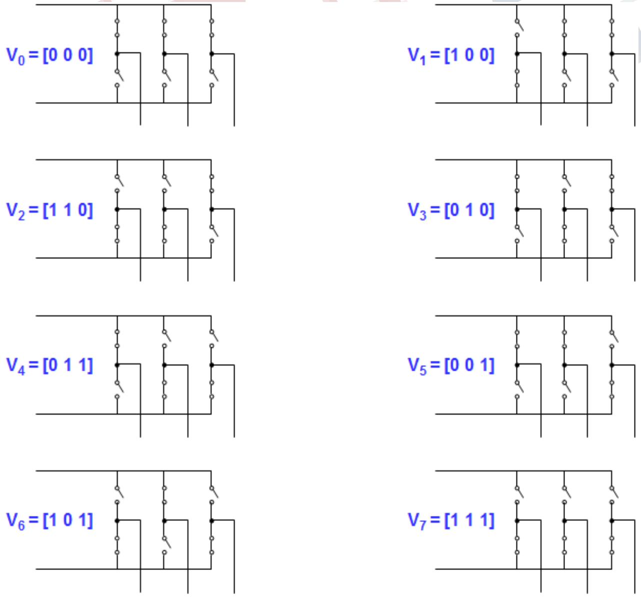

Fig.12 switching of eight inverter voltage vectors (V0-V7)

The modulation signals of SVPWM are as shown in fig.11

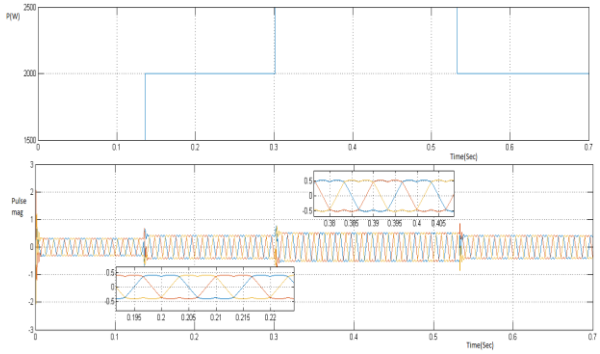

Fig.13 Power vs.SVPWM modulation

SYSTEM PARAMETERS

S.no	Quantity	Value	Units
1.	Rated power	3000	Watts
2.	Grid line to line voltage(V_{rms})	220	Volts
3.	Dc Link voltage	400	volts
4.	Frequency	60	Hz
5.	L_i	1.4	mH
6.	C_f	4.4	µF
7.	L_g	709	µH
8.	R_D	4.45	Ω
9.	Switching Frequency	7.8	KHz
10.	K_p,K_i	10,5000	-

Table.1 System Parameters

IV. SIMULATIONS AND EXPERIMENTAL RESULTS

We verified the proportional resonant controller by using SVPWM technique Simulations are done by using Mat lab/Simulink.The grid currents for various active powers are shown in figure.12, fig.13

1. ACTIVE POWER VARIATIONS

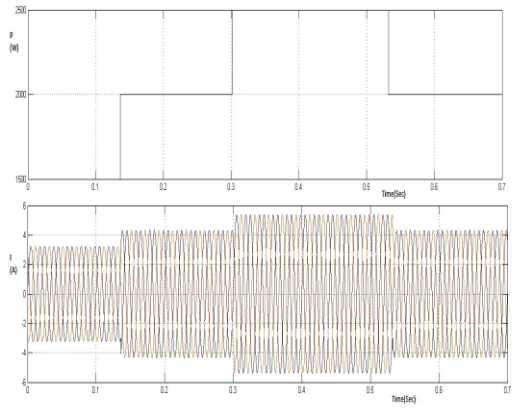

Fig.14 Active power vs. Currents

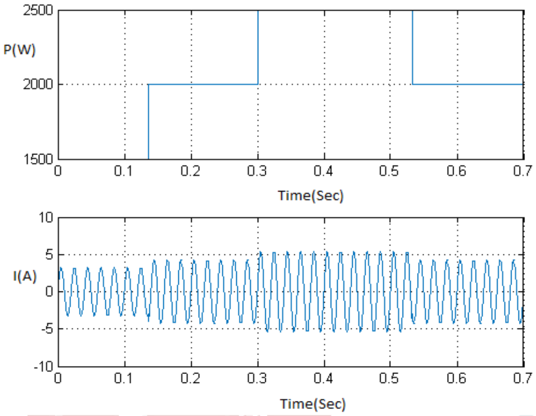

Fig.15 active power vs. single phase Currents

Fig.14 shows the grid voltages and currents wave forms for different values of active powers respectively.

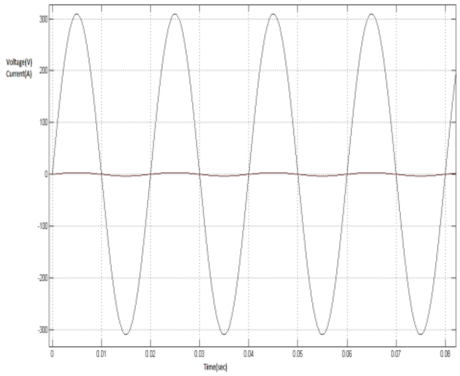

Fig.16 Voltage vs. currents for dynamic Active powers

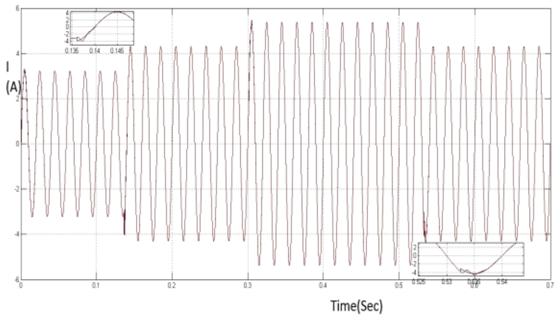

Fig.17 $I\alpha$ vs. Time

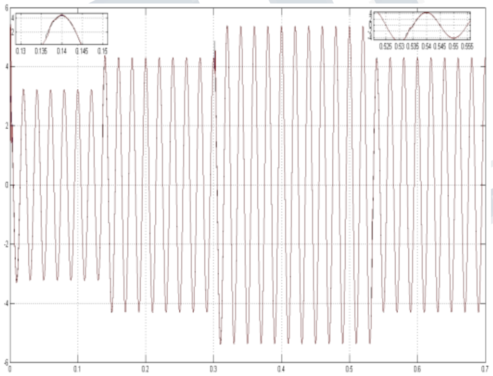

Fig.18 I_{β} vs. Time

2. REACTIVE POWER VARIATIONS

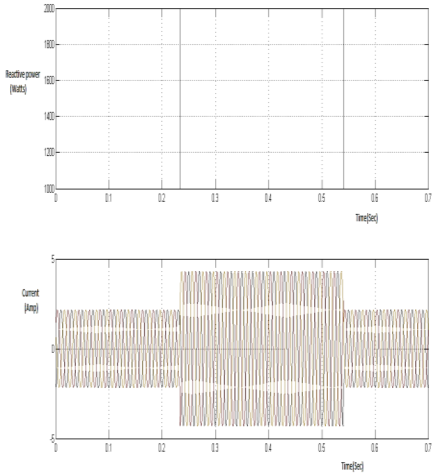

Fig.19 Reactive power vs. Currents

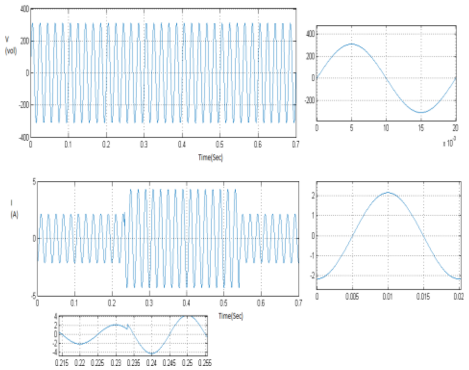

Fig.20 Reactive power vs. Voltage, Current

We can observe that under all dynamic conditions the voltages and currents are in phase with variation of active power in the system. Along with this we can also controlled the current harmonics. In the case of reactive power variation we can observe that current leads phase voltages and harmonics are regulated. Finally it is clear that the proposed controller provides smooth grid operation under various power variations.

V. CONCLUSION

In this paper we studied the Active and reactive power control by using PR controller with SVPWM technique .the design of LCL and PR controller is detailed. The controller operation for dynamic active and reactive power are simulated and analyzed. The desired grid currents and voltages are achieved. The smooth and fast response operation of the system was obtained. The proposed method also reduces the current harmonics in the system under various load conditions.

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