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Analysis of Active Power Factor Correction Using Single and Dual Mode Boost Converter

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Abstract: **The ratio between real or average power and apparent power known as power factor has a high impact on power system industries. Efficient usage of the real power is very indicative in developing a power system. In the nonlinear system, loads are the main source of harmonics. The current drawn by power electronic interfaces from the line is distorted resulting in a high total Harmonic Distortion and low p.f. this creates adverse effects on the power system include increased magnitudes of neutral currents in three phase systems, overheating in transformers and induction motors. This paper aims to develop a circuit for PFC by using active filtering approach by implementing two (single & dual) boost converters arranged in parallel, for improving circuit quality and switching loss. This work actually involves simulation of basic power electronic circuit We focused to improve the condition of input current waveforms for making it sinusoidal by tuning the circuits.**

Keywords: **Boost converter, Power factor, Dual Boost converter, Harmonics, Active PFC, Passive PFC, Average current mode control.**

I. INTRODUCTION

Converters are very essential elements in power electronics industries. AC to DC converter has a diode bridge rectifier with a high value of capacitor for filtering purpose. This capacitor cut downs the cost of the converter and makes it robust. However due to the presence of harmonic ac line current, the power factor is poor . The most common power quality disturbance is instantaneous power interruption. Various power factor correction (PFC) techniques are employed to overcome these power quality problems out of which the boost converter topology has been extensively used in various ac/dc and dc/dc applications. The basic boost topology does not provide a high boost factor. This has needed many proposed topologies as cascaded boot tapped inductor boost etc. This paper introduces another variation dual Boost PFC convertor addition in parallel with rectifier circuit to provide a higher boost factor and also provides proper controlling. This paper involves with PSPICE simulation of different types of electronic conventional rectifier circuit and voltage waveforms. It starts with simple rectifier circuit and different MOSFETs and switches to improve by implementing advanced techniques such as active PFC, where we mainly focusing on the objective of improving the input current waveform. All the simulation work is carried out/done in PSICE simulation manager.

II. POWER FACTOR WITH DIFFERENT LOADS

Power factor is defined as the cosine of the angle between voltage and current in an ac circuit. If the circuit is inductive, the current lags behind the voltage and power factor is referred to as lagging. However, in a capacitive circuit, current leads the voltage and the power factor is said to be leading. **Linear System:** It is AC electrical loads where the voltage and current waveforms are sinusoidal. The current at any time is proportional to voltage. Power factor is determined only by the phase difference between voltage and current. **Non Linear System:** Applies to those ac loads where the current is not proportional to voltage. The nature of the nonlinear current is to generate harmonics in the current waveform. This distortion of the current waveform leads to distortion of voltage waveform. Under this condition, the voltage waveform is no longer proportional to current. For sinusoidal voltage and non-sinusoidal current P.F can be expressed. or or ; Here, $cos\theta$ is the displacement factor of the voltage and current. Kp is the purity factor or the distortion factor. Another important parameter that measures the percentage of distortion is known as the current total harmonic distortion (THDi) which is defined as follows

PF= $(V_{rms}I_{1rms}/V_{rms}I_{rms})*\cos\Phi = (I_{1rms}/I_{rms})\cos\Phi = K_P \cos\Phi$

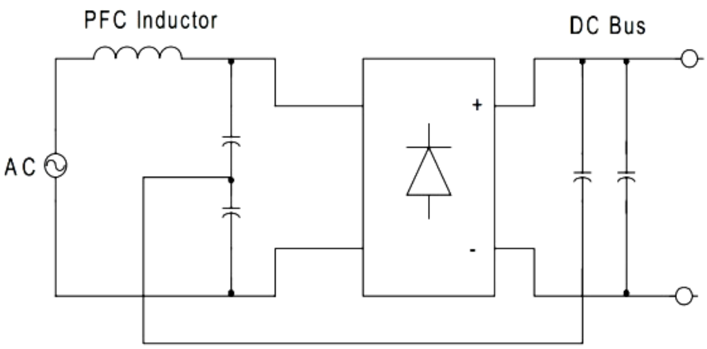
$K_P = (I_{1rms}/I_{rms})$ $K_P \in [0,1]$

III. EFFECTS OF HARMONICS ON POWER QUALITY

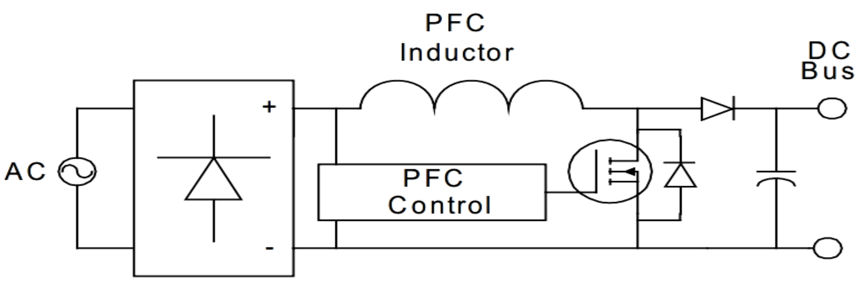
The contaminative harmonics can decline power quality and affect system performance in several ways. As presence of harmonics declaims the transmission efficiency and also creates thermal problems, both conductor and iron loss are increased. In 3-Φ system, neutral conductor becomes unprotected due to odd harmonics. Triggering is misconducted as the peak harmonics create currents which interrupts the protection system of an automatic relay. Huge current flows through the ground conductor of system with four wire 3-Φ when odd number of n- current is present in harmonics. Finally, harmonics could cause other problems such as electromagnetic interference to interrupt communication, degrading reliability of electrical equipment, increasing product defective ratio, insulation failure, audible noise etc .

IV. TYPES OF POWER FACTOR CORRECTION

Passive PFC: The simplest form of PFC is passive PFC. A passive PFC uses a filter at the AC input to correct poor power factor. The passive PFC circuitry uses only passive components: an inductor and some capacitor circuit requires only a few components to increase efficiency, but they are large due to operating at the line power frequency. Although pleasantly simple and robust, a passive PFC rarely achieves low Total Harmonic Distortion (THD). Also, because the circuit operates at the low line power frequency of 50Hz or 60Hz, the passive elements are normally bulky and heavy.



Active PFC : Active PFC offers better THD and is significantly smaller and lighter than a passive PFC circuit. To reduce the size and cost of passive filter elements, an active PFC operates at a higher switching frequency than the 50Hz/60Hz line frequency An active PFC circuit produces low THD and uses relatively small passive component .



BASIC PRINCIPLE OF BOOST CONVERTER:

Stepping up the power stage without isolating topology, the boost converter works perfectly. In practical field of power designing, required output should be always higher that input voltage. This topology is fulfilled perfectly with boost power stage. The basic working principle of boost converter is to generate non-pulsating input current to output diode as diode conducts only during a portion of the switching cycle. The output capacitor supplies the entire load current for the rest of the switching cycle.

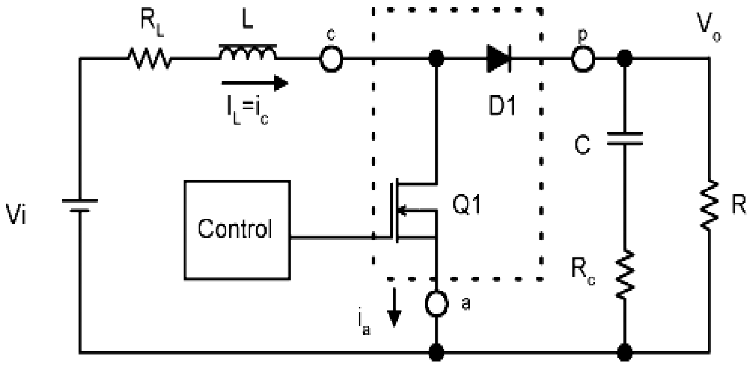


Figure4: Boost Power stage schematic diagram Boost power stage can work out both in modes considering continuity of current in the inductor. This current inductor mode current flows either continuously in the inductor during the entire switching cycle in steady-state operation or inductor current is zero for a portion of the switching cycle. A periodicity is maintained as it approaches towards peak value from zero and returns back to it during each switching cycle. It is desirable for a power stage to stay in only one mode over its expected operating conditions because the power stage frequency response changes significantly between the two modes of operation.

V. BASIC PRINCIPLE OF DUAL BOOST CONVERTER

Conventionally, boost converters are used as active Power factor correctors. However, a recent novel approach for PFC is to use dual boost converter i.e. two boost converters connected in parallel. Circuit diagrams for both types of PFCs are as given below:

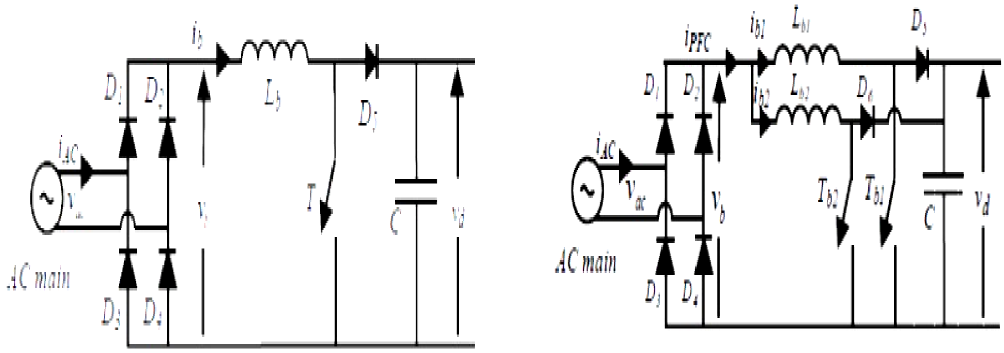
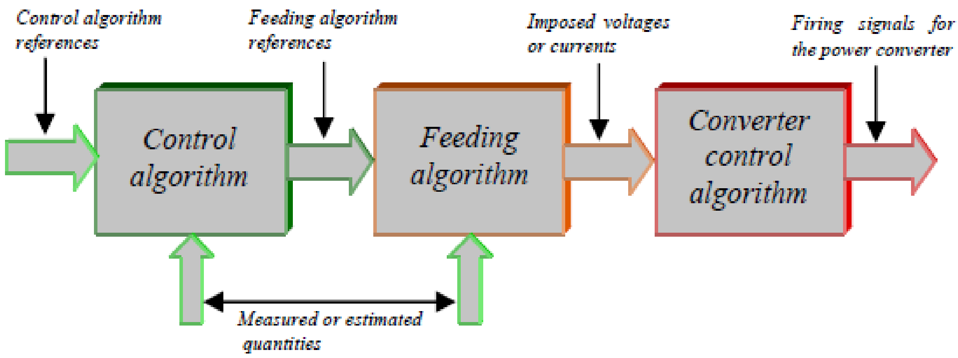


Figure 5: (a) Classical PFC circuit (b) Dual Boost PFC circuit [9] Here, we use a parallel scheme, where choke Lb1 and switch Tb1 are for main PFC while Lb2 and Tb2 are for active filtering. The filtering circuit serves two purposes i.e. improves the quality of line current and reduces the PFC total switching loss. The reduction in switching losses occurs due to different values of switching frequency and current amplitude for the two switches. The parallel connection involves phase shifting of two or more boost converters connected in parallel and operating at the same switching frequency.

VI. CONTROL PRINCIPLE OF DC-DC CONVERTERS

Control strategy for an electrical system is intended to develop a set of actions that can detect the time evolution of electrical quantities and to impose them to follow a desired time evolution. In general, a control algorithm can be split into three functional sub-blocks:



VII. SIMULATION AND RESULT

This paper deals with the current control common closed loop mode approach for PWM dc-dc converters, Signals in current form have a natural advantage over voltage signals. Voltage being an accumulation of electron flux, is slow in time as far as control mechanism is concerned. This led to the development of a new area in switch mode power supply design, i.e. the current mode control. Here, the averaged or peak current of magnetic origin is employed in the feedback loop of the switch mode power converters. It has given new avenues of analysis and at same time introduced complexities in terms of multiple loops.

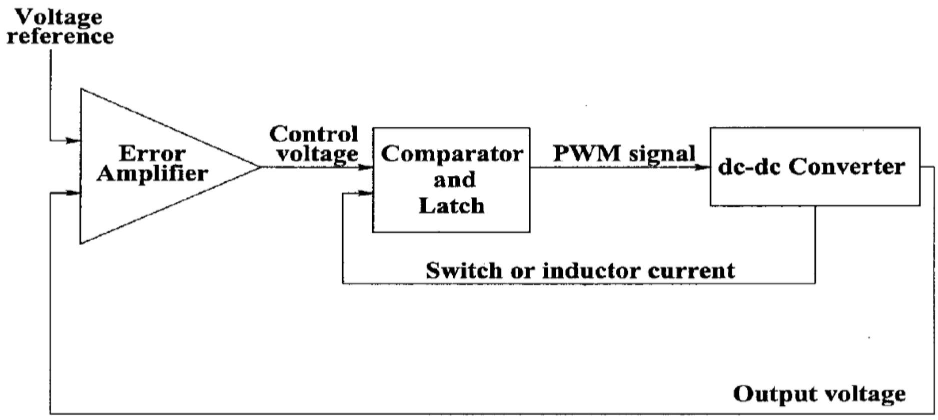
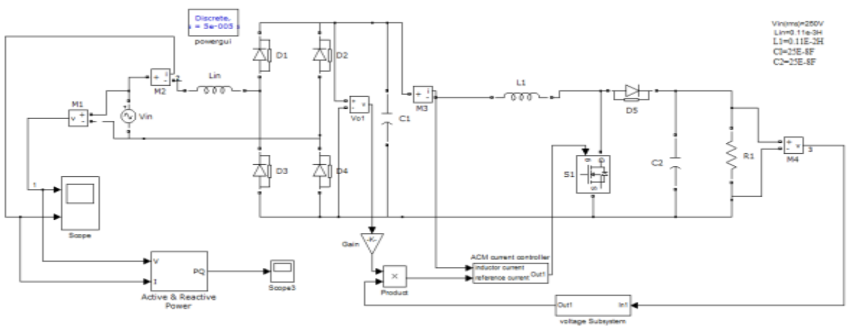
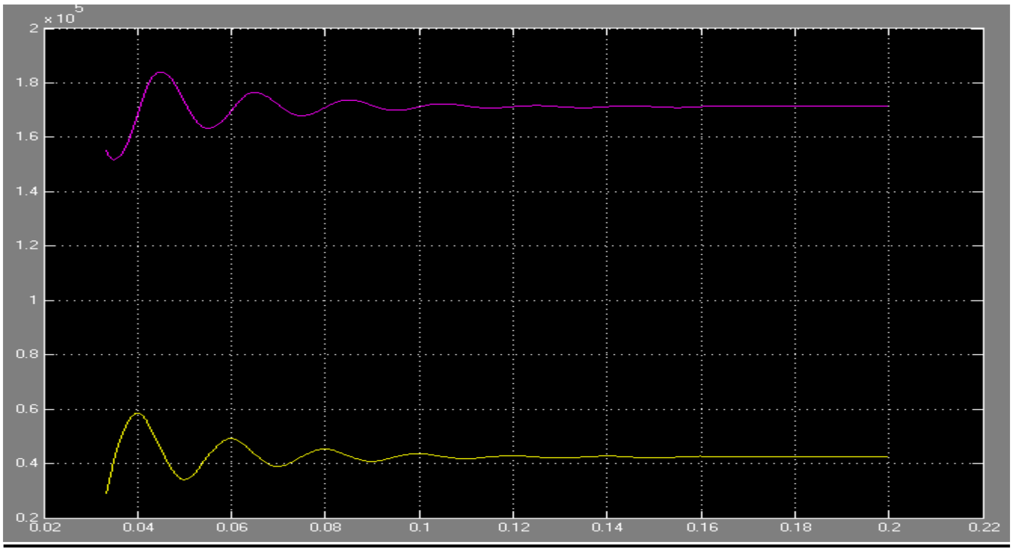


Figure 8: A current control mode A schematic diagram of current mode control is shown in Fig 8. It comprises of an additional inner control loop. The inductor current signal, converted to its voltage analog fed back by this loop is compared to the control voltage. The dynamic behavior of the converter is significantly altered by this modification of replacing the saw tooth waveform by the converter current signal. The key difference between voltage and current mode control is the way the reference map is generated. In the case of voltage mode control, the ramp is external from the viewpoint of the power plant, whereas for current mode control, it is internal.

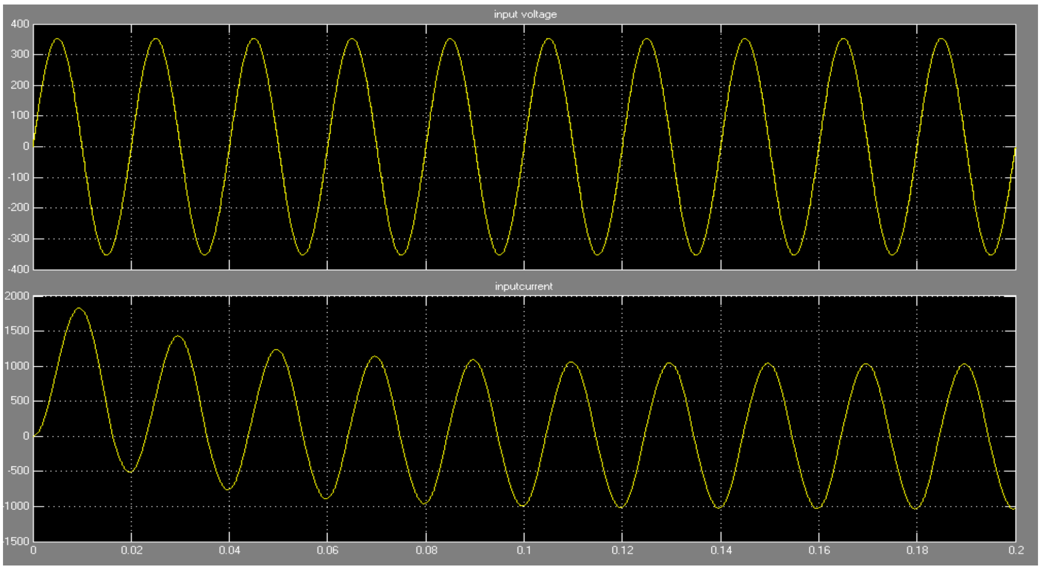
PFC CIRCUIT HAVING SINGLE BOOST CONVERTER:



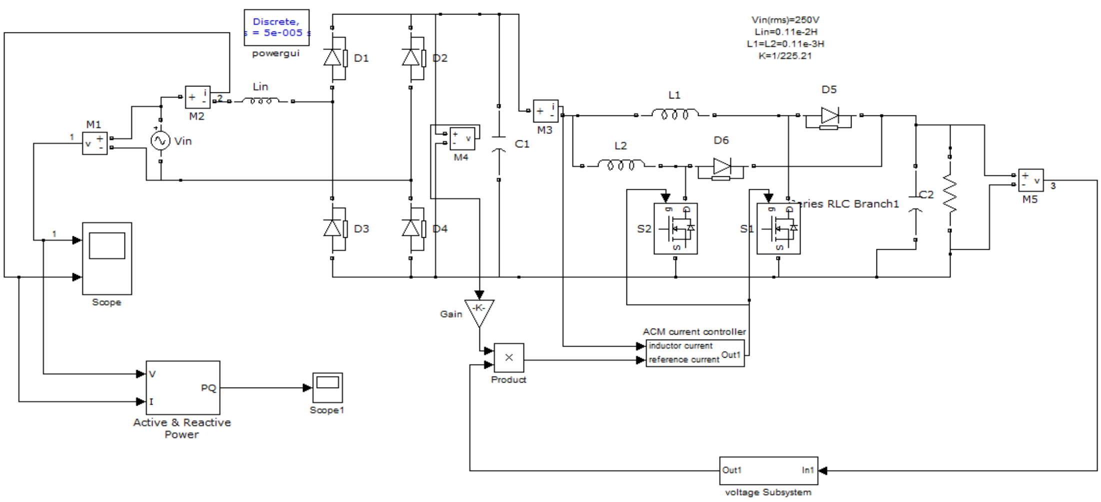
ACTIVE AND REACTIVE POWER:



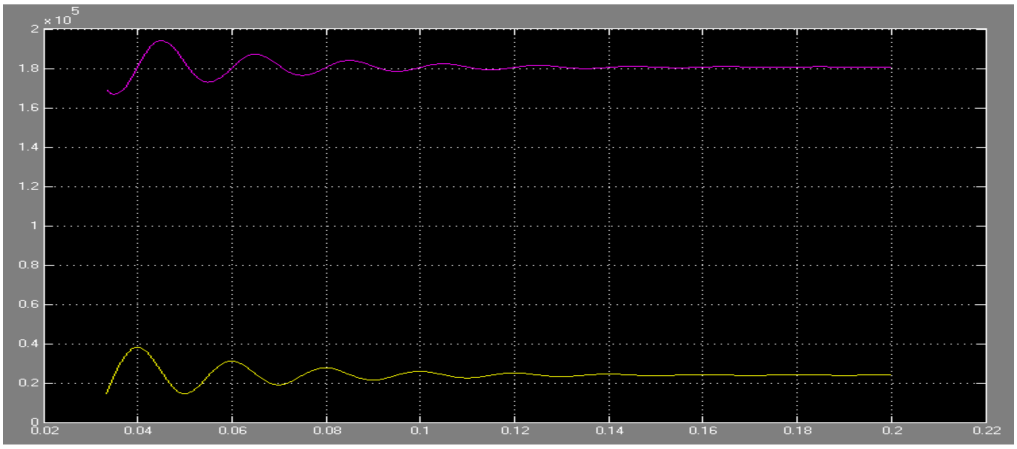
SIMULATION RESULTS:



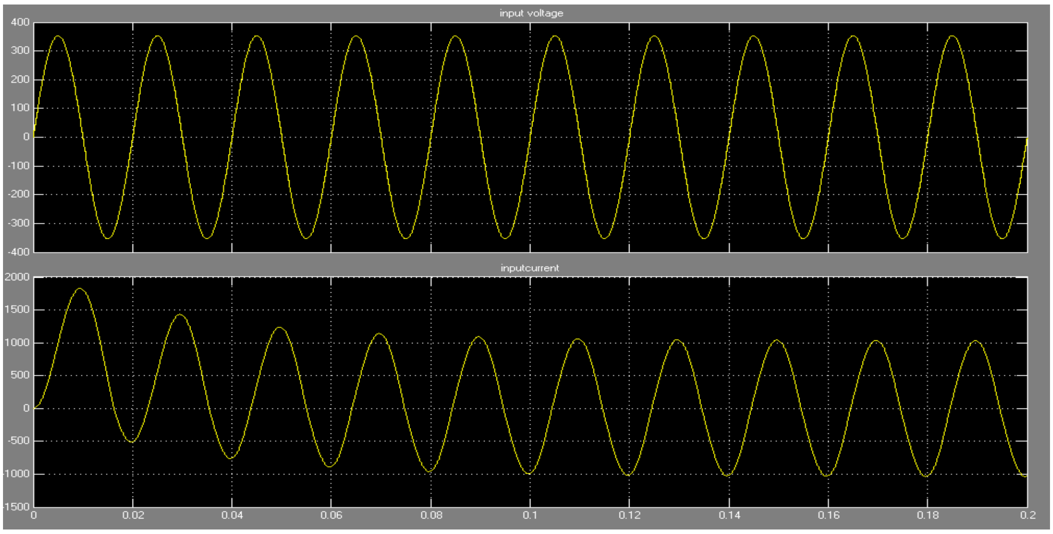
PFC CIRCUIT WITH A PARALLEL BOOST CONVERTER:



ACTIVE AND REACTIVE POWER:



SIMULATION RESULTS:



This figure shows that with feedback and using parallel boost converter which the PFC circuit works. Here ,in the 1st figure ,we see that without using feedback circuit the V-I curve starts at approximately in millisecond ,which represents that p.f is not that improved .But if we add a feedback circuit thisphenomenon is been improved. Table I.: Analysis of different PFC circuits[9]

SI.No	Circuit	Power Factor
1	Conventional Rectifier (without boost converter)	0.9706
2	Boost Converter without feedback	0.989
3	Boost Converter with feedback	0.99

IX. CONCLUSION

The power factor corrections with boost converters are simulated by PSPICE simulator link. In this paper conventional converter, we used the parallel topology of boost converter to correct the power factor and brought it near unity by elimination of harmonics effects step by steps, when first one improves and second one filtering the power factor. Here we use one n-type and one p-type MOSFET instead of using two a kind and a smaller fractional value of PF range capacitor across the R-L load, this paper will be most innovative and important handbook to improve the power factor for non-linear loads.

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