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Modeling and Analysis of a Novel Voltage Controlled Hybrid Active Power Filter in Distribution systems

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Abstract:

A novel voltage controlled hybrid active power filter (HAPF) is proposed. Whenever the power system undergone through different inductive, loadings load reactive power may vary. This voltage controlled HAPF improves the power factor nearest to unity, source harmonics can be reduced and reactive power compensation can be provided.

By using hysteresis current pulse width modulation (HPWM, current reference) start-up self charging methodology might be gotten and also giving compensation of reactive power. Finally, representative simulation results of a novel voltage controlled hybrid active power filter are displayed to confirm all conclusions, furthermore demonstrate the adequacy of all proposed novel voltage control scheme.

Keywords:

Reactive power compensation,hybrid active power filter(HAPF), hysteresis pulse width modulation(HPWM).

I.INTRODUCTION:

Increase in non-linear loads may cause power quality problem in the power system. It is happening manifest in an abnormal voltage, current or frequency deviations. These deviations results in less efficiency, life expectancy and misoperation [1], [2].

As the power electronic equipment such as rectifiers used in industrial equipment may produce harmonics, these harmonics there will be a serious effect on the ability system and the plants distribution system.

And some more parameters such as sags, swells, harmonics and other disturbances, with in these a serious power quality concern is current harmonics and the other is reactive power compensation. As to deliver the active power, a voltage is to be for the reactive power is to be maintained.

When the reactive power is not enough the voltage sags down and the active power demanded by the loads will be less. Unless reactive power, many of the electrical devices may get less efficiency and it shows harmful effects on electrical appliances. So, the reactive power compensation is needed.

In the olden days, a filter named as passive LC filter is used. It is to be connected in parallel with the lines and it is grounded. But, there are some disadvantages using passive LC filters [3], such as overloads can happen because of the harmonics coming from the non-linear loads and it may get affected by the nearest passive filter, these cannot be suitable for variation in loads as that of the demanded and source current harmonics will be guaranteed if the filter impedance is longer than the source impedance [4].

In 1976, Gyugui first developed the concept of active power filters (APFs) [5]. The disadvantages inherent in passive filters are overcome by the APFs. APFs are relatively high initial and operating cost due to its high inductive loadings [6].

Presently, hybrid active power filters (HAPFs) are proposed which is the combination of active and passive filters, where the active part is the power electronics devices and the passive part is the RLC components. This combination improves the compensation characteristics of the passive filters and reducing the ratings of voltage/current ratings of APFs [7].

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II.CIRCUIT DIAGRAM OF LC-COUPLING HAPF:

A. Circuit diagram of 3-φ, 4-wire LC-coupling HAPF:

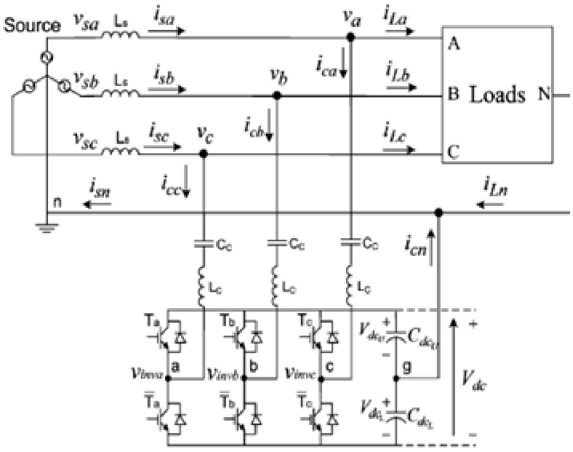

Fig.1: Circuit diagram of 3-φ, 4-wire LC-coupling HAPF

The circuit diagram of three phase four wire LC-coupling HAPF is shown in fig.1. The i_a, i_b, i_c are the three phase source currents and $i_n$is the neutral current, the subscript a, b, c denotes three phases and n is the neutral and it can be written as i_x where x denotes a, b, c. v_{sa}, v_{sb}, v_{sc} are the three source voltages, L_s the very low inductance and it can be neglected; then V_{sx}≈V_x, V_x is the load voltage. i_{La}, i_{Lb}, i_{Lc}Are load currents, i_{ca}, i_{cb}, i_{cc} are the compensating currents. C_c *and* L_cAre the compensating capacitor and compensating inductor and these are coupled and given to each phase. C_{dcU} *and* C_{dcL}Are the upper and lower capacitors connected to the neutral side? Voltage at C_{dcU} is $V_{dcU}$and voltage at C_{dcL} isV_{dcL}. The combination of both V_{dcU} and $V_{dcL}$is the V_{dc}.
Therefore, $V_{dc} = V_{dcU} + V_{dcL}$.

B.Single phase equivalent circuit diagram of three phase four-wire LC coupling HAPF

The single phase equivalent circuit diagram is shown in fig.2.

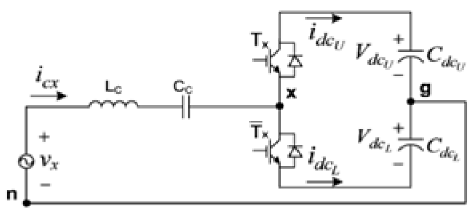

Fig.2: Single phase equivalent circuit diagram of three phase four-wire LC coupling HAPF.

From the fig.2, the i_cx can flow either T_x or (T_x and it can enters into C_dcU or C_dcL and returns through the neutral wire. The transistors used here are insulated gate bipolar transistors (IGBTs).
The capacitor voltages are shown below

$$V_{dcU} = \frac{1}{C_{dcU}} \int i_{dcU}\, dt$$

$$V_{dcL} = \frac{1}{C_{dcL}} \int i_{dcL}\, dt \qquad (1)$$

Where $i_{dcU}$and$i_{dcL}$are the upper and lower dc currents respectively.

$$i_{cxU} = S_x i_{cx}$$
$$i_{dcL} = (1 - S_x) i_{cx} \ldots\ldots\ldots\ldots\ (2)$$

Where, S_x is the switching function in x-phase.

By substituting (2) in (1), then

$$i_{dcU} = \frac{1}{C_{dcU}} \int S_x i_{cx}\, dt$$

$$i_{dcL} = \frac{1}{C_{dcL}} \int (1 - S_x)\, i_{cx}\, dt \ldots\ldots\ldots\ldots\ (3)$$

$S_x = 1$, if $T_x = 1$ $\overline{T_x} = 0$
$= 0$, if $T_x = 0$ $\overline{T_x} = 1 \ldots\ldots\ldots\ldots\ldots\ (4)$

In equation (4), 1 or 0 is the binary state of the two switches such as T_x and $\overline{T_x}$.
The switching logic is shown below,

If$i_{cx} > (i^*_{cx} + h_b)$, T_x is ON and $\overline{T_x}$ is OFF; then S_x = 1

If $i_{cx} < (i^*_{cx} - h_b)$, T_x is OFF and $\overline{T_x}$ is ON; then S_x = 0
Hysteresis pulse width modulation is used [8].
Where $h_b$is hysteresis and i^*_{cx} is the reference compensating current.

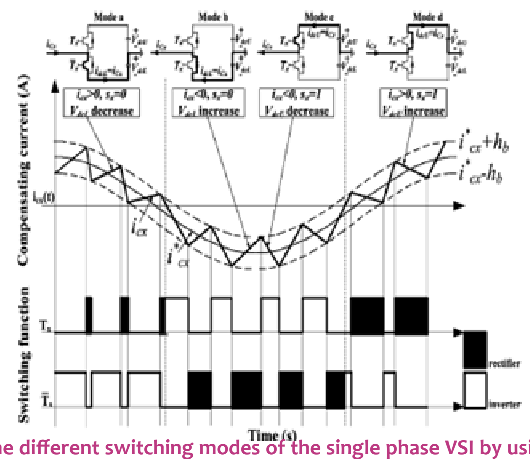

Fig.3: The different switching modes of the single phase VSI by using hysteresis pulse width modulation (HPWM).

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From fig.3, the changes in voltages of V_dcU and V_dcLat different modes are shown in table I.

TABLE I
The changes in capacitor voltages at different modes:

Switching mode	i_{cx} conditions	Switching function	Operating circuit	Change of DC capacitor voltage
A	$i_{cx} > 0$	$s_x = 0, T_x = 0, \bar{T}_x = 1$	Inverter	V_{dcL} *decrease*
B	$i_{cx} < 0$	$s_x = 0, T_x = 0, \bar{T}_x = 1$	Rectifier	V_{dcL} *increase*
C	$i_{cx} > 0$	$s_x = 0, T_x = 0, \bar{T}_x = 1$	Inverter	V_{dcU} *decrease*
D	$i_{cx} < 0$	$s_x = 0, T_x = 0, \bar{T}_x = 1$	Rectifier	V_{dcU} *increase*

III CONTROL SCHEME FOR LC-HAPF BY USING A NOVEL VOLTAGE CONTROL METHOD

A.The instant power compensation control block:

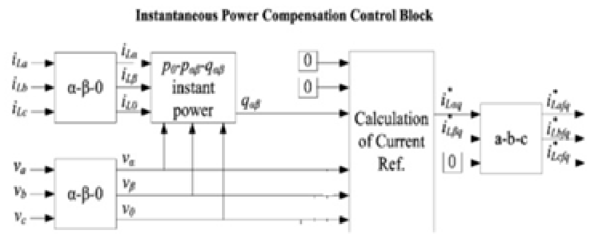

Fig.4: The instant power compensation control block

From the above compensation block, the fundamental loading reactive currents are determined such as $i^*_{Lafq}, i^*_{Lbfq}, i^*_{Lcfq}$ are determined. This is shown below [9].

From the above block,

$$q_\alpha = v_\alpha * i_{L\alpha} \sin\emptyset$$

System parameters	Physical values	
Source	V_s	55V
	L_s	1mH
LC-HAPF; ($Q_{cxf_{PPF}} = -145.1VAR$)	L_c, C_c	6mH, 140μF
	$V^*_{dc}/2$	30V
1^{st} *inductive loading*	R_{L1}, L_{L1}	12Ω, 30mH
1^{st} and 2^{nd} inductive loadings	R_{L1}, L_{L1}	12Ω, 30mH
	R_{L2}, L_{L2}	17.5Ω, 30mH

$$q_\beta = v_\beta * i_{L\beta} \sin\emptyset$$

The outputs of the above block $= \frac{(q_{\alpha\beta}v_\beta + q_{\alpha\beta}v_\alpha)}{v_\alpha * v_\beta}$

$$= \frac{q_{\alpha\beta}(v_\alpha + v_\beta)}{v_\alpha * v_\beta}$$

$$= i^*_{Lafq}$$

Similarly, i^*_{Lbfq} and i^*_{Lcfq} are calculated.

B.Proposed novel voltage control block:

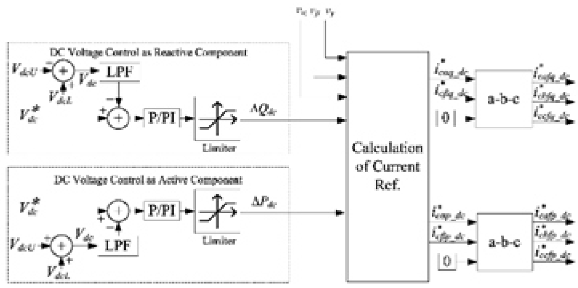

Fig 5: The proposed novel voltage control block.

The upper and lower dc voltages are summarized to get V_{dc} and is given to the low pass filter to filter frequency noise and is to be compared with the V^*_{dc}. The compared output is given to the P/PI controller and then to limiter to get ΔQ_{dc} and ΔP_{dc}. The overflow problem can be avoid by the limiter.

Thus, $i^*_{cafq\ dc}, i^*_{cbfq\ dc}, i^*_{ccfq\ dc}, i^*_{cafp\ dc}, i^*_{cafp\ dc}$ and $i^*_{cafp\ dc}$ are calculated and given to the pulse width modulation control block.

C.Current pulse width modulation control block:

By summing the i^*_{Lafq}, $i^*_{cafq\ dc}$ and, $i^*_{cafp\ dc}$, i^*_{ca} can be obtained. Similarly i^*_{cb} and i^*_{cc}. This is shown below fig 6. The output of the summation block, i^*_{ca} and compensating current i_{ca} are given to the pulse width modulation control block to control switches of the power electronic devices of inverter.

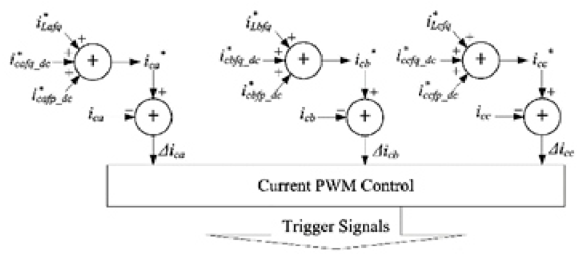

Fig 6: Current pulse width modulation control block.

IV.SIMULATION RESULTS:

The parameters for simulation results are shown below table II.

TABLE II

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The total results are carried out in MATLAB/SIMULINK software. When the first inductive loading is connected without any compensation, the results are $Q_{Lxf} = 121.8, DPF = 0.7864, i_{sx} = 3.52$. When the first and second inductive loadings are connected, the results are $Q_{Lxf} = 176.6, DPF = 0.852, i_{sx} = 6.08$. Without any compensation, load reactive power is more.

A. Without Voltage Control Proposed Method.

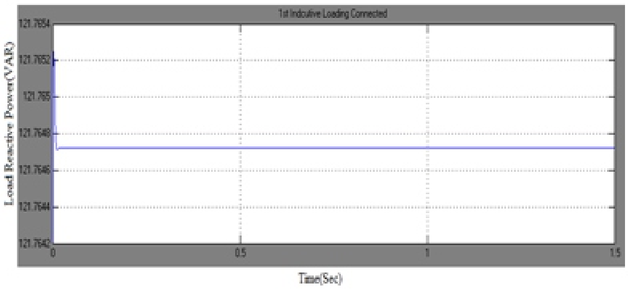

Fig. 7: Load Reactive Power without Compensation When 1stinductive loading is connected.

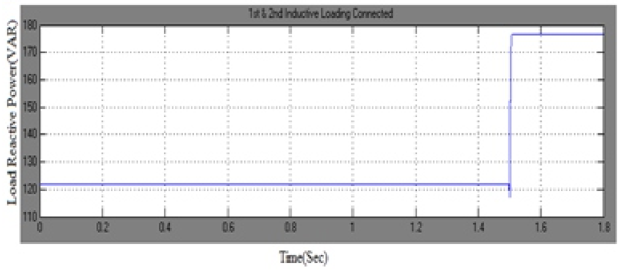

Fig. 8: Load Reactive Power without Compensation When 1st& 2nd loadings are connected.

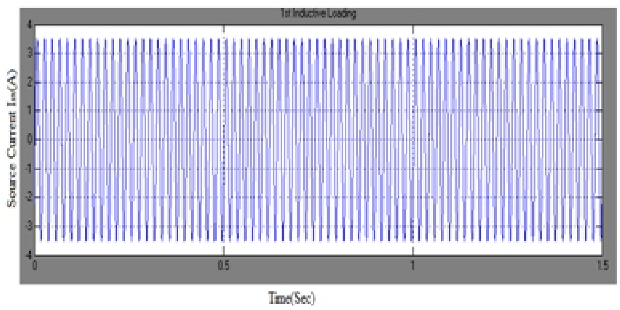

Fig. 9: Source Current without Compensation When 1stinductive loading is connected

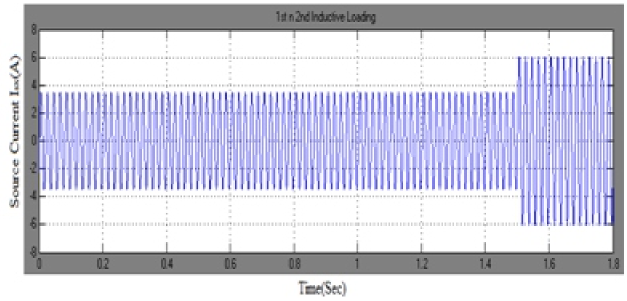

Fig. 10: Source Current without Compensation When 1st& 2nd inductive loadings are connected

B. With Voltage Control Proposed Method:

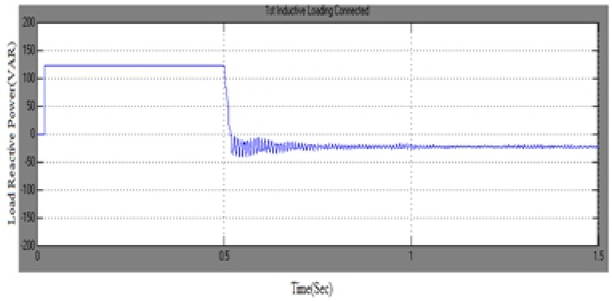

Fig. 11:Load Reactive Power With Compensation When 1stinductive loading is connected.

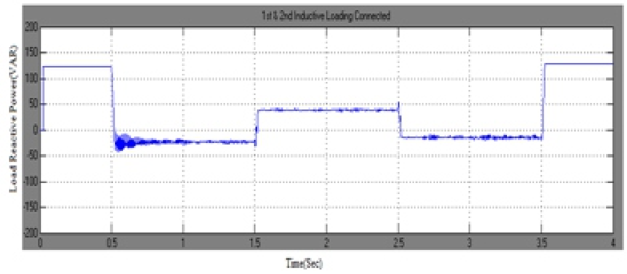

Fig. 12:Load Reactive Power With Compensation When 1st& 2nd inductiveloadings are connected

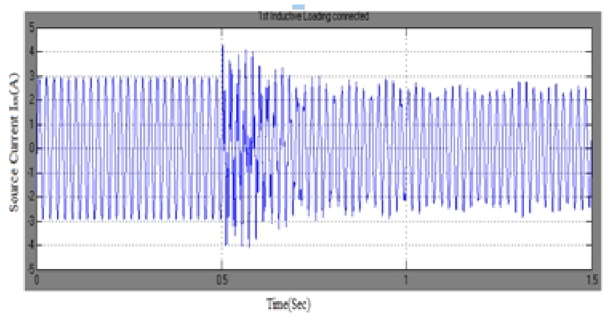

Fig. 13: Source CurrentWith Compensation When 1stinductive loading is connected

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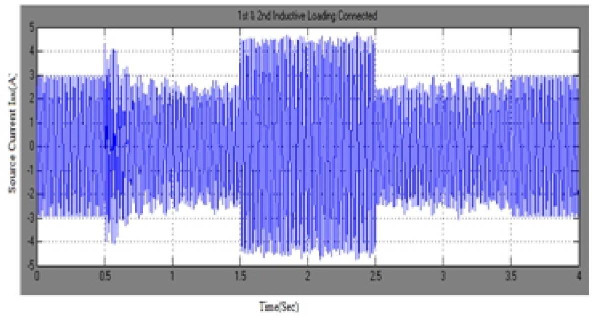

Fig. 14: Source CurrentWith Compensation When 1st&2ndinductive loadings are connected.

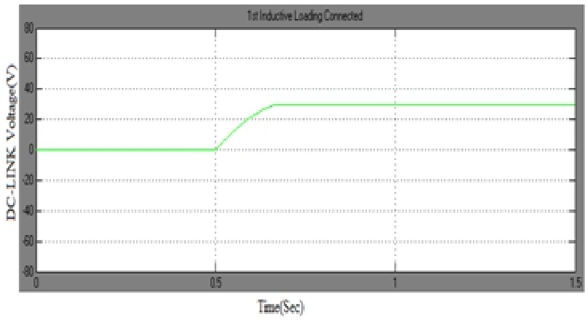

Fig. 15: DC Voltage control when 1stinductive Loading is connected.

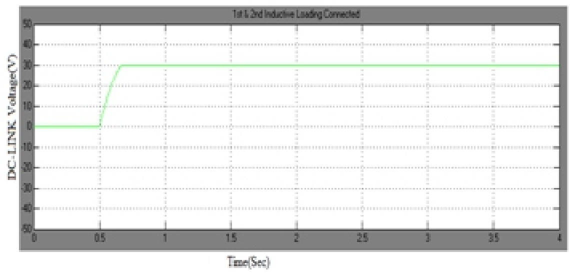

Fig. 16: DC Voltage control when 1st& 2ndinductive Loading is connected.

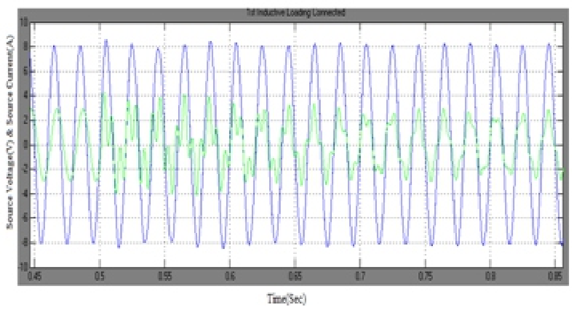

Fig. 17: Source Voltage & Source Current when 1stinductive Loading is connected.

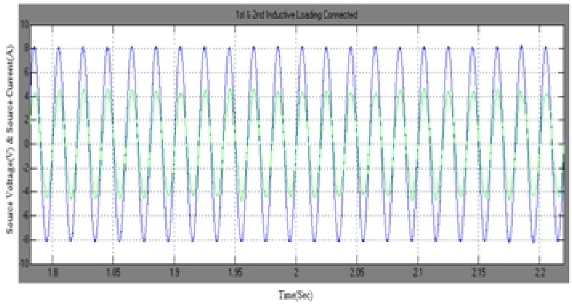

Fig. 18: Source Voltage & Source Current when 1st& 2ndinductive Loading is connected.

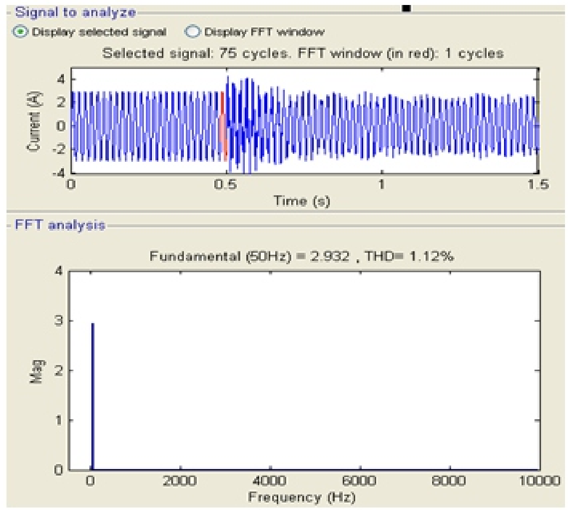

Fig 19: THD when first inductive loading is connected after compensation.

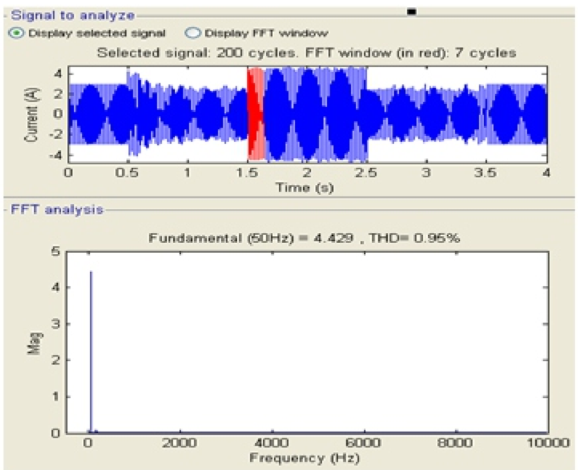

Fig 20: THD when first and second inductive loadings are connected after compensation.

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TABLE III

Simulation results of before and after compensation with a novel voltage control.

Before compensation				After compensation			
Different cases	Q_{Lxf}	DPF	i_{sx}	Q_{sxf}	DPF	i_{sx}	THD
1^{st} *Inductive loadding*	121.8	0.7864	3.52	-18.4	0.9901	2.9	1.12
1^{st} *and* 2^{nd} inductive loadings	176.6	0.852	6.08	38.03	0.9872	4.6	0.95

V.CONCLUSION

Finally, simulation results of the novel voltage controlled HAPF are shown with before and after compensation and show the effectiveness of the proposed novel voltage control method.

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