Design of DVR against Voltage Sags & Swell Using Matrix Converter

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***Abstract*— This paper is describes the using of dynamic voltage restorer (DVR) in the terms of mitigate voltage sagging and swelling with low voltage distribution systems. A dynamic voltage restorer (DVR) is based on the dq_o algorithm. This scheme is very effectual to notice any trouble in low voltage distribution systems. Simulation results using Matlab/Simulink are existing to make sure the usefulness of the proposed scheme.**

***Keywords*— dynamic voltage restorer (DVR), voltage sags, voltage swells, matrix converter, matlab/simulink.**

I. INTRODUCTION

Faults at either the transmission or distribution level may cause voltage sag or swell in the entire system or a large part of it. Also, under heavy load conditions, a significant voltage drop may occur in the system. Voltage sags can occur at any instant of time, with amplitudes ranging from 10 - 90% and a duration lasting for half a cycle to one minute [1].

There are different methods to mitigate voltage sags and swells, but the use of a convention Power device is measured to be the well-organized method. The concept of convention Power was introduced by N.G. Hingorani in 1995.

A. Power Quality Problem

Power Quality problems cover a wide ranges of conflicts such as voltage sags/swells, impulse transient, flicker, harmonics distortion and interruptions. These sags/swells have mainly importance in power quality problems in the power distribution system. The power quality troubles are performing its impact on a variety of customer like Industries, commercial, residential. Most important quality problems are voltage sag, swell, transients, and harmonics, so on.

The power quality troubles are performing its impact on a variety of customer include Industries, Commercial as well as residential. Most important quality problems are voltage sag, swell, transients and harmonics and so on. Power quality phenomenon can be defined as the variation of the current and voltage from its ideal waveform.

Power Quality has developed into an unsafe issue in highly automated industries and sensitive load centers. The voltage disturbances in the form of voltage sag, swell, flicker and harmonics can cause huge financial losses. In the past few years, power system solutions have been avoiding these troubles. The main difficulties of poor power quality like voltage sag for sensitive loads can be improved solution based upon Dynamic Voltage Restorer (DVR).

B. Voltage Sag

Voltage sag is defined as the drop of RMS voltage among 0.1 p.u. and 0.9 p.u. and durable between 0.5 cycles to 1 minute. Voltage sag are typically cause by the fault of the system. It is caused by asymmetrical line to line, single and double-line-to-ground and symmetrical three phase faults effects on sensitive loads, the DVR injects the voltages to restore and maintain the sensitive to its supposed value The insertion power of the DVR with minimum power for compensation purposes can be achieved by selecting an amplitude and phase angle.

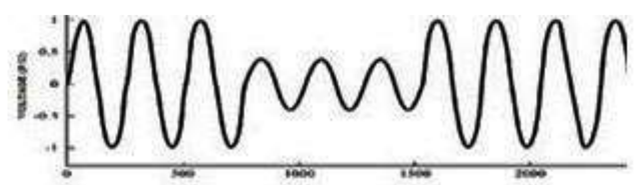


Fig. 1 Voltage sag and swell

Voltage sag and swell can cause by the failing of the sensitive equipment like shutdown, large unbalance current, fuses or trip breakers. It may be very expensive for the customers. With the use of Dynamic Voltage restorer it Dynamic Voltage restorer can be eliminate this problem.

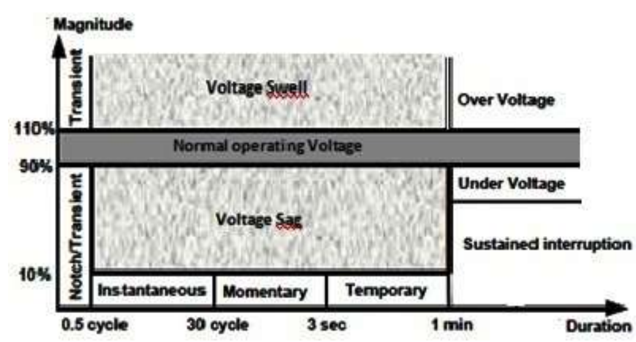


Fig. 2 Voltage Reduction Standard of IEEE Std. 1159-1995.

C. Solution of Power Quality

In general, there are two come within reach of followed to alleviate the tribulations associated with power quality. First approach is called load training, which guarantees that the equipment is less perceptive to power turbulence permitting the operation still below significant voltage deformation and the second approach is to mount line conditioning schemes that suppress or neutralizes the power schemes turbulences.

The procession conditioning system or convenience side solutions will participate a major role in improving the inherent supply quality; some of the effective and economic measures can be identified which are as follows: Lightening and Surge Arresters, Thyristors Based Static Switches, Energy Storage Systems, Harmonic Filters etc.

D. DVR

A Dynamic Voltage Restorer (DVR) is series connected devices that inject supply voltage into the system; to control the load voltage. DVR was installed at the first time in 1996. Generally it is installed in a distribution system between the supply and load feeder. Its most important function is to quickly boost up the load voltage in form of disturbance in order to avoid any power disruption in load. There are varieties of circuit topology and control scheme that can be used to apply a DVR. In the addition of voltage sags and swells compensation, DVR has some other features such as: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations.

1) Location of DVR: The supplement of a DVR at the low voltage 4-wire 440 V level is shown in Fig.3. The increase in impedance by insertion of a small rated DVR can be significant for the load to be protected from voltage dips. Thereby, the per cent change in the impedance (*Zincrease*, %) in can be increased by several hundred percent.

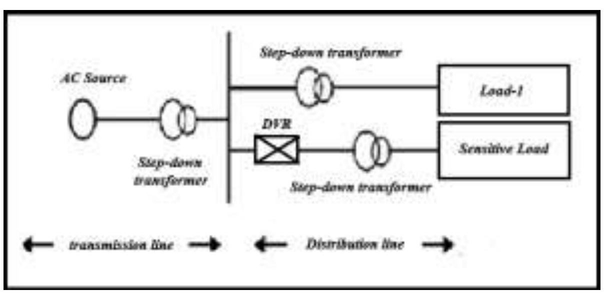


Fig.3 *Location of DVR*

The advantages with a LV solution are:

- The DVR can be attempted more specific voltage dip in sensitive loads.
- The DVR can both be placed by the consumer at the consumer domain have to be access in LV-level.
- The DVR is easier to protect and decreased the short-circuit level by the distribution transformer

The disadvantages with a LV solution are:

- The value of impedance increases after the adding of the DVR.
- Its protected load can be large.

2) *Principle Operation of DVR:*

Along with the voltage transients (sags, swells, harmonics…so on), the voltage sags are the many disturbance. The users may improve by the uses of some devices or use protection devices to diminish the amount of voltage sags. But on the whole solution to diminish the voltage sags and recovering the load voltage to the pre-fault value is using a Dynamic Voltage Restorer (DVR). It is DC to AC switching converters that inject three single-phase AC voltages in series between the feeder and sensitive load. Using a DVR is more reliable and quick solution to maintain with a clean supply of electricity for customers. But standby losses, equipment costs and required large investigation for design are the main drawbacks of DVR.

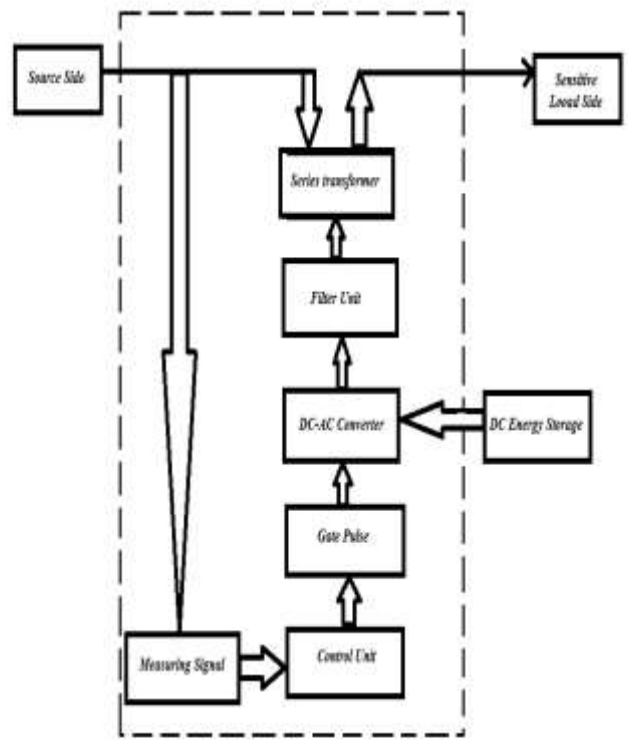


Fig.4 *Principle of DVR*

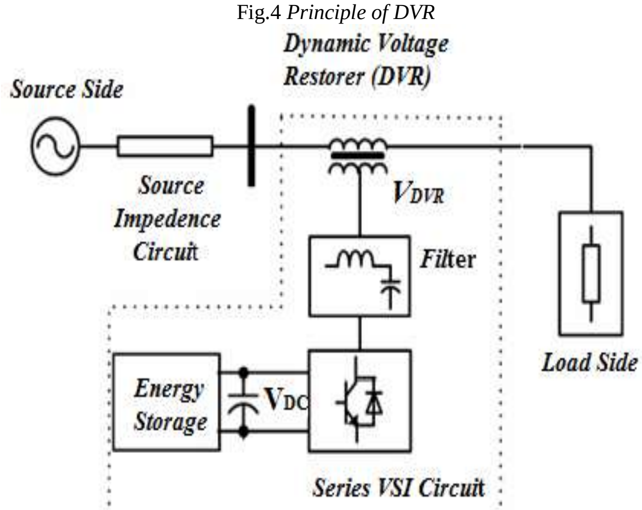


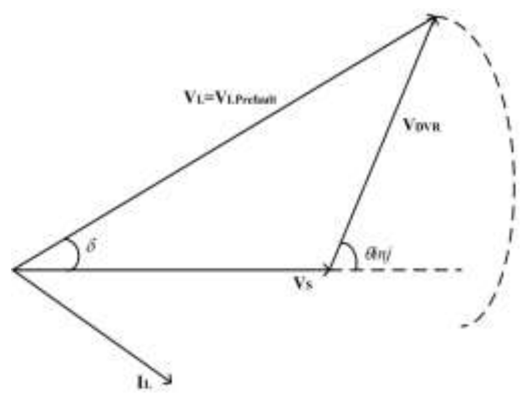
Fig.5 Basic Structure of DVR

D. Methods of Voltage Injection on DVR

The methods of DVR voltage injection are classified into four sections. Some loads are very sensitive to phase angle jump and others are tolerant to it. So, the controlled policy depends on the type of the characteristics of load. Compensation of voltage sags is dependent upon the DVR power rating, different types of load conditions and different types of voltage conditions.

1) Pre-dip compensation (PDC)

During fault and pre-fault conditions, the pre-dip/sag compensator is track the continuously & compensated load supply voltage. In this method, ideal value of the load voltage can be restored, but active power can't be controlled. It can be determine the type of fault and load conditions of the system. The main drawback of this technique is it requires a higher capacity energy storage device. In this case V_{DVR} is the voltage injected by the DVR, which can be obtained as:



According to the figure the apparent power of DVR

$$S_{DVR} = 3I_l V_{DVR}$$
$$= I_l\sqrt{V_l^2 + V_s^2 - 2V_lV_s\cos(\theta_l - \theta_s)}$$

and active Power of DVR is:

$$P_{DVR} = 3I_l(V_l cos\theta_l - V_s cos\theta_s)$$

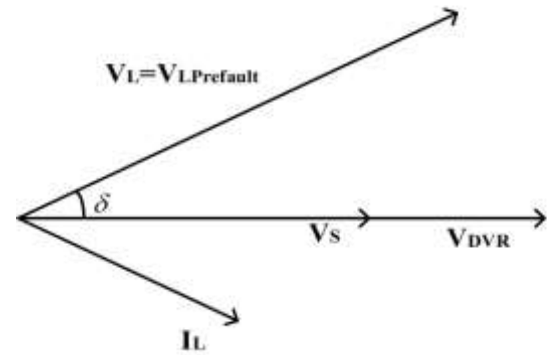
the magnitude and angle of DVR voltage are:

$$V_{DVR} = \sqrt{V_l^2 + V_s^2 - 2V_lV_s\cos(\theta_l - \theta_s)}$$

$$\theta_{DVR} = \tan^{-1}\left(\frac{V_l\sin(\theta_l) - V_s\sin(\theta_s)}{V_l\cos(\theta_l) - V_s\cos(\theta_s)}\right)$$

2) In-Phase compensation (IPC)

In-Phase compensation is the straight forward method and it is used in which the injected DVR voltage is in phase to the supply side voltage apart from of the load current and the pre-fault voltage as shown in Figure-3. The IPC method is appropriate for minimum voltage or minimum energy operation strategies. This approach need large amount of real power to diminish the voltage sag.



According to the figure the apparent power of DVR

$$S_{DVR} = 3I_l V_{DVR}$$
$$= 3I_l(V_l - V_s)$$

And active Power of DVR is

$$P_{DVR} = 3I_l(V_{DVR}cos\theta_s)$$
$$= 3I_l((V_l - V_s)cos\theta_s)$$

The magnitude and angle of DVR voltage are:

$$V_{DVR} = (V_l - V_s)$$
$$\theta_{DVR} = \theta_S$$

3) In-Phase Advanced Compensation Method (IPAC

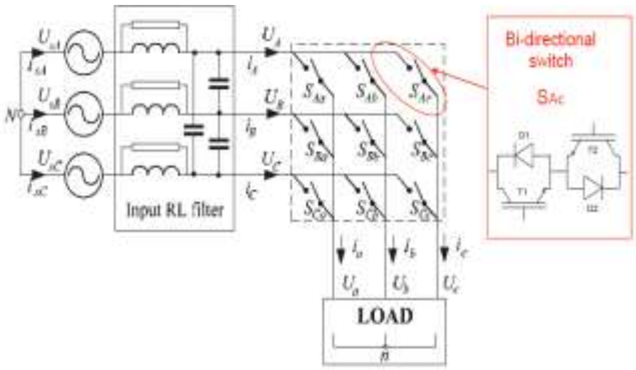
In this method the real power exhausted by the DVR is decreased by minimize the power angle between the voltage sag and load current. In this method, the dynamic power is usually inject into the system for the period of disturbances. In short, IPAC method uses only reactive power and unfortunately, al1 the sags cannot be mitigate without any real power, as a result, this method is appropriate only for a limited sag ranges

4) Voltage Tolerance Method with Minimum Energy Injection

This compensation method will maintain the load voltage within the tolerance area with small change of voltage magnitude.

E. Matrix Converter

The matrix converter is consists by the combination of 9 Bi-directional (18 IGBT + 18 Diodes) switches that allocate any output phase to be linked to any input phase. The circuit scheme is shown in figure…….the figure corresponds to the 3x3 way. Matrix converter can convert AC/AC electrical power in direct form and its needs to be protected against the overvoltage. The over current that may be critical for its semiconductor devices. It is totally operates upon variable frequency & variable voltage.

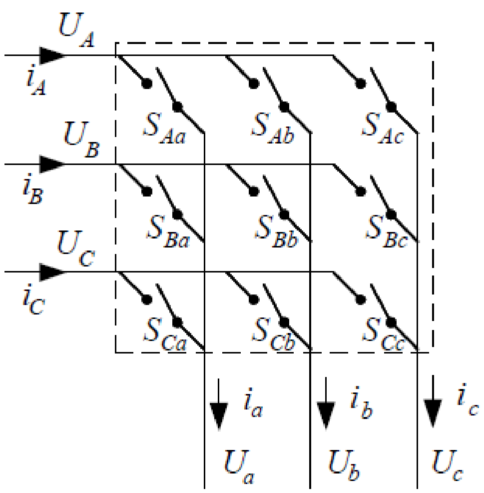


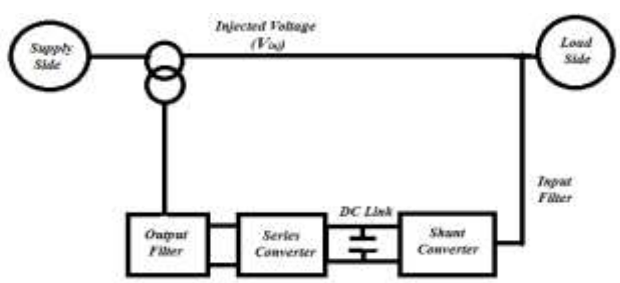
The DVR is voltage injected device to compensate the voltage drop with the factors of voltage sag. The DVR is restores the load voltage (through its rated value). There are two types of DVR in general:

1. DVR with no energy storage system
2. DVR with energy storage system.

Each type has two topologies:

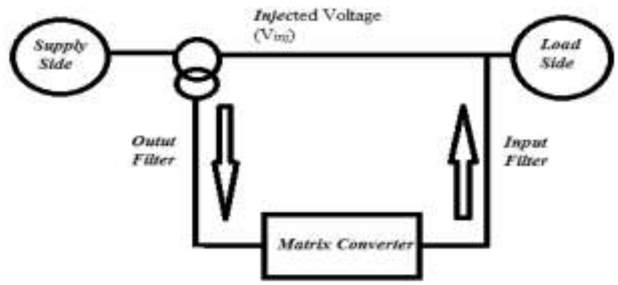
1. supply-side connected converter
2. Load-side-connected converter.





fig….DVR with no energy storage & Load side connect Converter

The matrix converter based DVR, here a DVR with both of no energy storage and load-side connected converter. According to Fig………….. there are two converters can be replaced by a *matrix converter and can be removed the DC-link capacitor.*



Fig….. Matrix converter based upon DVR

The supply voltage of matrix converter comes from the load and the matrix converter output is directly connected to an injection transformer. Matrix converter can control the necessary reparation voltage and injects that voltage throughout the transformer. To diminish the harmonics, matrix converter's input and output are supplied with filters. There is no energy storage mechanism and the energy is in used from the grid.

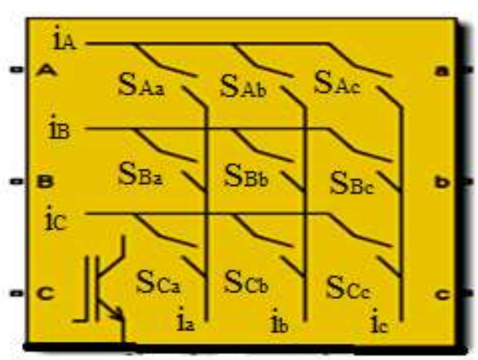
F. Switching arrangement of Matrix Converter

There are two possible configuration ways of building the bi-directional switch:

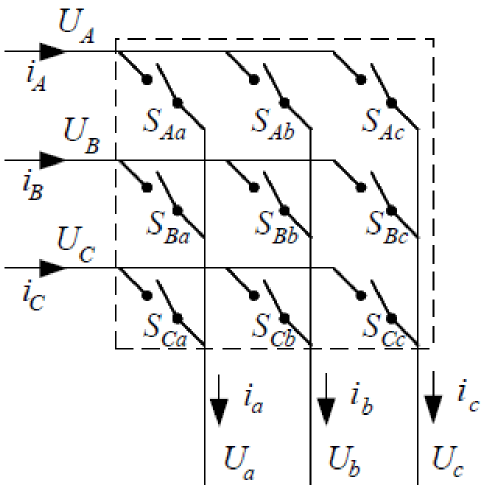
- *A transistor embedded in a diode bridge configuration (two anti-paralleled transistors and anti-parallel diodes).*
- *The configuration can be used as either a Common Emitter (CE) or a Common Collector (CC).*

G. Principle of Operation

The Single-Phase Matrix Converter (SPMC) consists by the combination of input and output lines matrix with four bi-directional switches which is connecting to the single-phase input to the single phase output. The Single-Phase Matrix Converter (SPMC) is existing schematic diagram in Fig 4.1 Its instant input voltage is $v_i(t)$ and output voltage is $v_o(t)$. It comprise of four switches S1, S2, S3, and S4 which is capable for blocking forward voltage and reverses voltages (symmetrical devices). Without any delays, the switching can be connected between the states. Fig…………. Single-phase matrix converter circuit arrangement at no load.



H. Fundamental operation of Matrix Converter



Switching function:

$$\mathbf{S_{io}}(t) = \begin{cases} 1, & Open \\ 0, & Close \end{cases}$$

i = $\{A, \quad B, \quad C\}$
o = $\{a, \quad b, \quad c\}$

Transfer Matrix:

$$[T] = \begin{bmatrix} S_{Aa}(t) & S_{Ba}(t) & S_{Ca}(t) \\ S_{Ab}(t) & S_{Bb}(t) & S_{Cb}(t) \\ S_{Ac}(t) & S_{Bc}(t) & S_{Cc}(t) \end{bmatrix}$$

This injected voltage is added up with the sag voltage and full output is obtained at the load.

$$V_{LK}(t) = V_{GK}(t) + V_{injK}(t) \text{ ; for K= 1,2,3}$$

In equation ……. L, G and inj are the load, grid, and injected quantities correspondingly. Also, subscript k refers to the number of phases and its value is 1, 2 and 3. For the duration of voltage swell condition, the negative voltage is injected to the line. To control the switching operation of matrix converter the "Least Mean Square Error" method can be used. It can balance voltage sag, swell, harmonics and flicker, because bidirectional switches are used in matrix converter.
There are two probable designing ways of the bi-directional switch

- A transistor embedded in diode bridge arrangement
- A transistor embedded in two anti-paralleled transistors and anti-parallel diodes.

I. Reduced Matrix converter

Reduced matrix converter (RMC) is a suitable topology which can be used as to reduce the size and weight of the converter. Reduced matrix converter (RMC) is increase the efficiency intrinsic conversion to less stage. The RMC provides direct AC-AC conversion without any need of a bulky DC link capacitor; we can say that it is a compact solution. Its main advantages are adjustable or unity power factor, bi-directional power flow, elevated quality waveform, and the possibility of a compact design due to the lack of large energy storage components. It gives the sinusoidal input and output waveforms among minimal higher order harmonics and no sub-harmonics; the input power factor can be controlled properly.

The proposed matrix converter has following advantages.

- The matrix converter consists with 4 bi-directional switches.
- Line to Line (L-L)short circuits at the input is overcome by varying the switching pattern
- That is means of commutation control.
- At output, the Open circuit is overcome by varying the switching pattern.

J. Application

1. Standard:

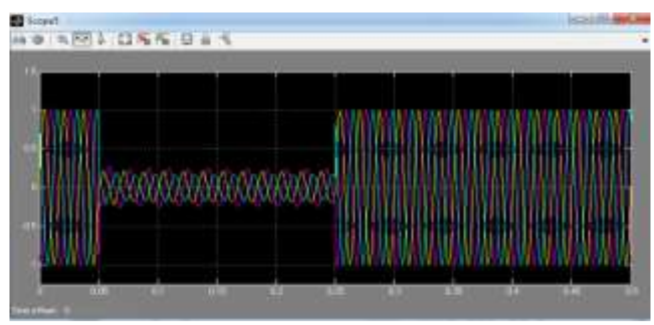
- Wind/Water Force Machines (blowers, boilers, incinerators), pumps, and general Industrial Machines.

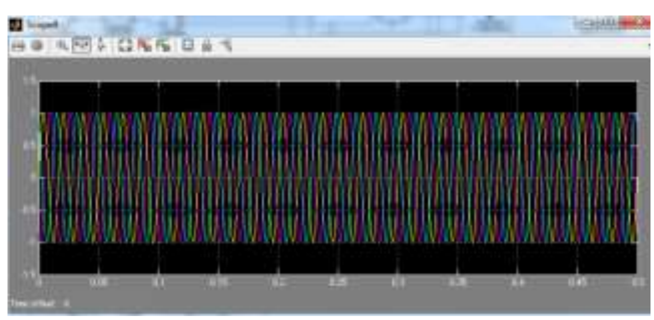
2. Specific Applications:

- Compact or Integrated Motor Drives
- Motor Drives for hostile environments (aircrafts, submarines)
- AC/AC Power Conversions: wind energy, variable speed drives...

3. Now a day's also this topic is in research.

K. Simulation Result





II. CONCLUSIONS

The modeling and simulation of Dynamic voltage Restorer (DVR) are presented by the usage of MATLAB/ SIMULATION. The simulation shows the satisfactory performance of DVR in The case of voltage sag and swell. Simulation result ma shows effective custom power of voltage sag and swell. The simulation carried out the better voltage regulation capability of DVR. Dynamic voltage Restorer (DVR) is handling both balanced and unbalanced position without any problem.

The main advantage of DVR is consider To be efficient result has been provided with low cost, fast response, compact size and its control is simple. As a result This DVR model can use to restore load voltage in The case of balance and unbalance condition of voltage sags and swells.

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