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Performance Evaluation of Adjustable Speed Drives with DSTATCOM

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Abstract*—Adjustable speed drives (ASD) employing induction motors are widely used in the industrials and process control in the form of varied applications such as fans, compressors, Pumps etc. They are energy efficient and can result in substantial energy saving when properly installed. However, they inject high harmonic content into current drawn from the ac system. This paper deals with the application of a DSTATCOM for compensation of such loads. The MATLAB / Simulink based models are developed for adjustable speed drive loads. The analysis is carried out with and without DSTATCOM. The results shown in the paper proves that DSTATCOM can be used as a good harmonic filter. This paper presents the enhancement of harmonic distortion and low power factor using Distribution Static Compensator (D-STATCOM).The model is based on the Voltage Source Converter (VSC) principle. The D-STATCOM injects a current into the system to improve harmonic distortion and low power factor. The simulations were performed using MATLAB SIMULINK version R2012b.
***Keywords*—Distribution Static Compensator(DSTATCOM),Adjustable Speed Drives(ASD),Flexible AC Transmission Systems(FACTS)**

I. INTRODUCTION

Custom power devices especially DSTATCOM can be used as very effective filter. It need not be designed to eliminate a particular harmonic infact a DSTATCOM unit can be designed to eliminate all lower order harmonics introduced by the drive system. This paper discusses the application of DSTATCOM for reducing total harmonic distortion in supply current. The shunt compensator may be designed utilizing fast switching IGBTs switches. The control logic is developed to produce an output current which when injected into the ac lines stops harmonic migration to the power source and alleviates the need for the source to supply reactive current.

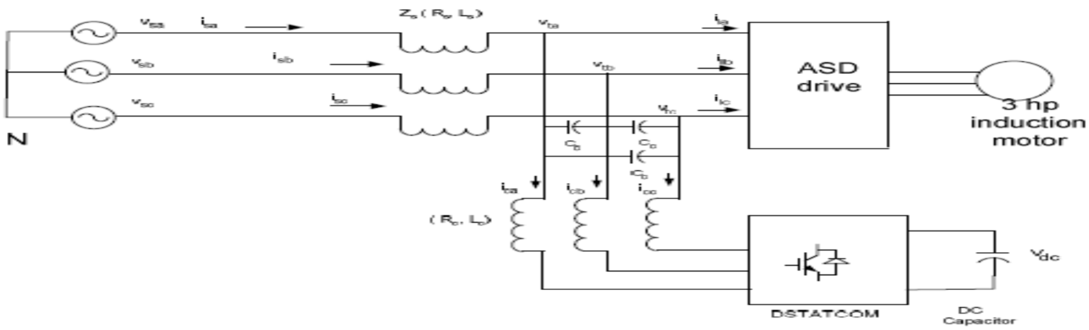
Good performance under system perturbations makes it an effective compensator. The best feature of this shunt compensator is that it can operate for lagging/ leading/ unity power factor loads and provide reactive Harmonic disturbances and their study has been a topic of research and today we can find a whole array of devices used to mitigate such problems. The ever growing use of power electronic based systems has aggravated the harmonics problem. These devices themselves well as the neighbouring loads. Literature review indicates the problems, effects and solutions for harmonics in power systems. Different type of low voltage loads can also introduce harmonics in the power network and adversely affect on the overall performance and operation of the power system. In this paper, use of custom power device for harmonic reduction is studied. Adjustable speed drives employing the use of induction motors are widely used in process control in varied applications. The mainbenefit from ASDs is that their energy efficiency to the tune of 30-50%. This feature alone makes them very attractive to consumers. ASDs also improve system efficiency, equipment reliability, enhance product quality and reduce product waste and the noise level. However, the ASDs use power electronic devices for their switching operation which inject harmonics into the connected system.

The increased penetration of these drives in electric utility system produces high harmonic content in current and voltage. The harmonic currents result in excessive heating in rotating machines. The harmonic currents, depending on their frequency, cause additional rotating magnetic fields in the motor. The magnetic field due to fifth harmonic, being the most prevalent tries to weaken the main field and rotates the motor in the opposite direction as the fundamental. Harmonic currents also cause overheating due to high-frequency eddy currents and hysteresis losses in the stator and rotor core and skin-effect losses in the windings. A comprehensive literature review is available on custom power devices which were invented by Hingorani and are being used in distribution systems. Power quality problems in distribution system mainly include poor power factor, poor voltage regulation and harmonics. Also, additional problems due to studied and system design has to be through. The trend nowadays is shift focus from passive filters to active filters. Some problems related to passive filters include selective filtering, large sized inductors and capacitors are needed and they are prone to detuning and compensation in both lead/ lag Vars.

II. PROPOSED ADJUSTABLE SPEED DRIVES CONFIGURATION

Figure.1 shows the block diagram of the system with DSTATCOM connected in shunt configuration. Nonlinear load on the system is modelled in the form of adjustable speed drive feeding induction motor load. DSTATCOM is modelled as a three-phase IGBT (Insulated Gate Bipolar Transistor) bridge based VSI (voltage source inverter) with dc bus capacitor at the DC link. Switching ripples need to be eliminated so smallcapacitors (Cc) have been used. The VSI bridge is connected to the three phase, three wire system via three input inductors (Lc, Rc). The role of these inductors may also be played by transformer.

Fig.1. Block Diagram of the System with DSTATCOM



Adjustable Speed drive (ASD) operation includes a rectifier and a converter. The first mechanism is the converter operation which injects harmonic currents into the supply system by an electronic switching process. The second mechanism is the inverter operation which can introduce additional ripples into the DC link current. These ripples penetrate into the supply system side. The extent and the frequency of inverter-caused ripples depend on inverter design and motor parameters. The current analysis of the load current injected into the system shows a high THD of over 95% with a predominance of 5th and 7th harmonics. The most common three phase converter is a six-pulse unit. Its characteristic shows high 5th and 7th content. Adjustable Speed Drive is as shown in Figure.2.

Table.1: Magnitude of harmonic vs. order for adjustable speed drives

Harmonic Order	5	7	11	13	17	19	23	25
Magnitude as a% of order	74.9	55.1	19.2	9.9	7.9	6	3.4	3.3

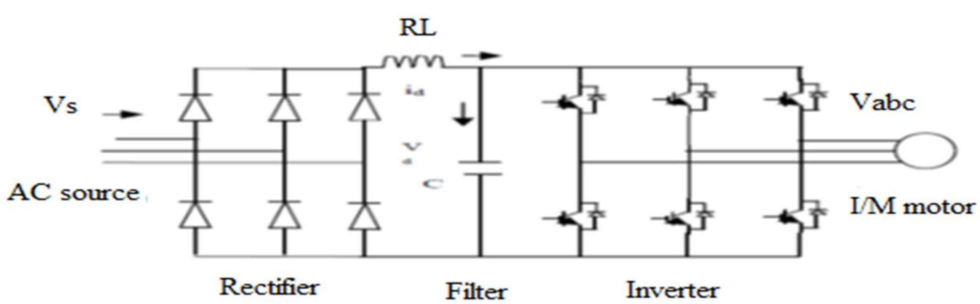


Fig.2: Block diagram of ASD

The modelling of the supply can be given using the state space derivative form of equations and represented as

$$V_{sa}-V_{ta}-i_{sa}R_s-L_p i_{sa}=0 \quad - \quad 1$$

$$V_{sb}-V_{tb}-i_{sb}R_s-L_p i_{sb}=0 \quad - \quad 2$$

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$$V_{sc}-V_{tc}-i_{sc}R_s-L_p i_{sc} = 0 \quad - \quad 3$$

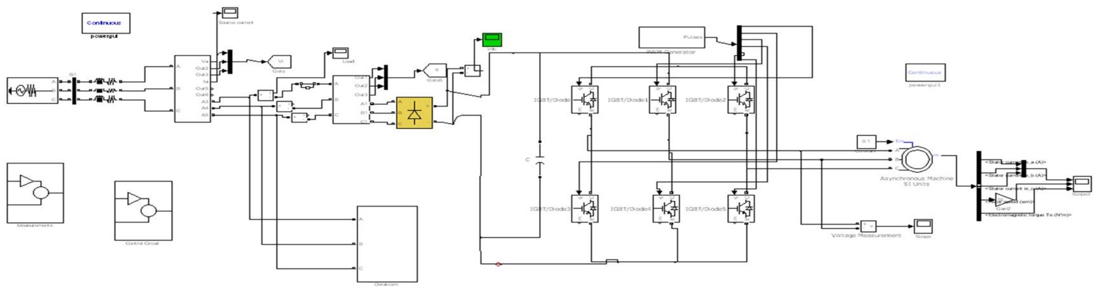

Fig.3: Simulation diagram of ASD

III. SIMULATION RESULTS FOR ADJUSTABLE SPEED DRIVES

Following results shows adjustable speed drive simulation results without DSTATCOM. Figure. 4 represents the source current with respect to time for a 3-phase system without DSTATCOM. The Figure.5 represents the fundamental harmonics with respect to frequency. The first order harmonics is above 80% withoutDSTATCOM and the THD valueis 101.25% .The Figure. 6 represents the load current waveform and its variations with respect to time. The Figure.7 represents the power factor without DSTATCOM.

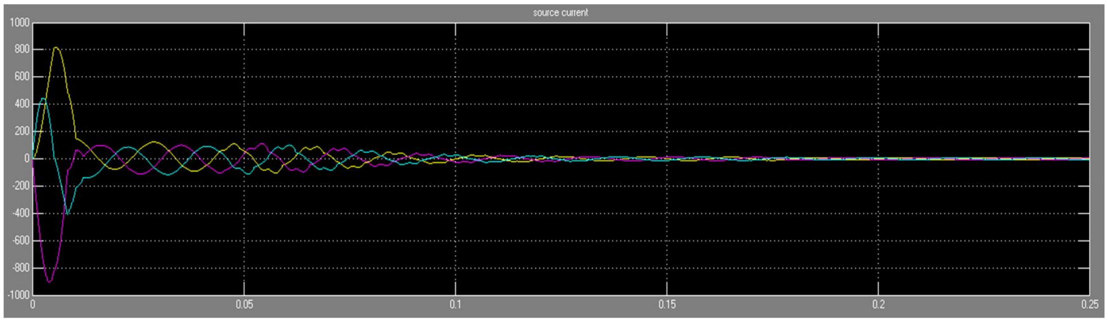

Fig.4: Source Current without DSTATCOM

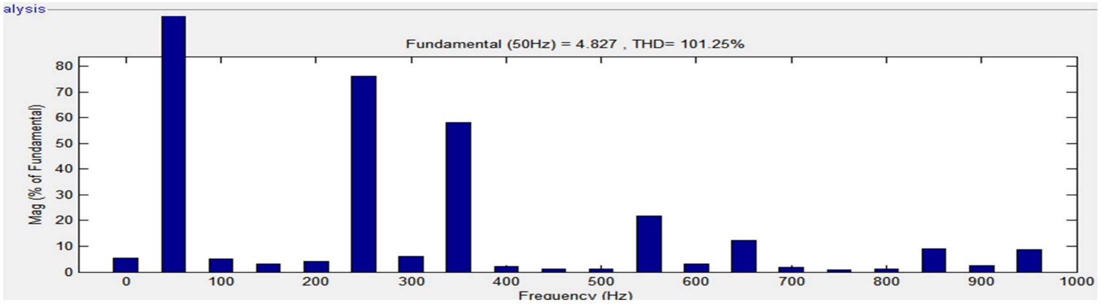

Fig.5: THD of Load Current Analysis without DSTATCOM

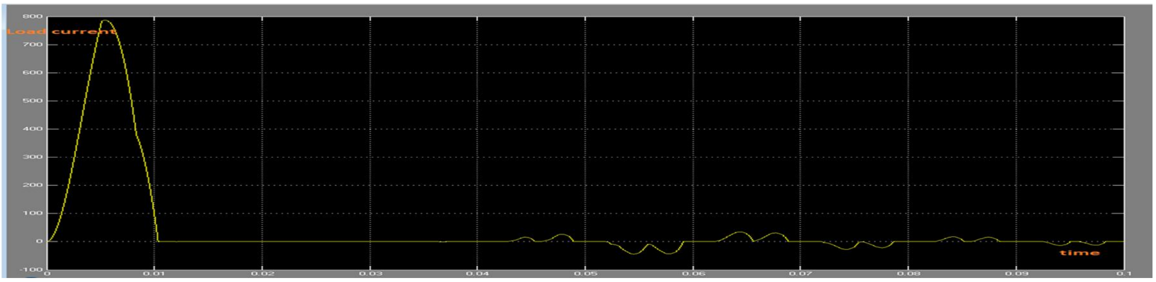

Fig.6: Input load wave form without DSTATCOM

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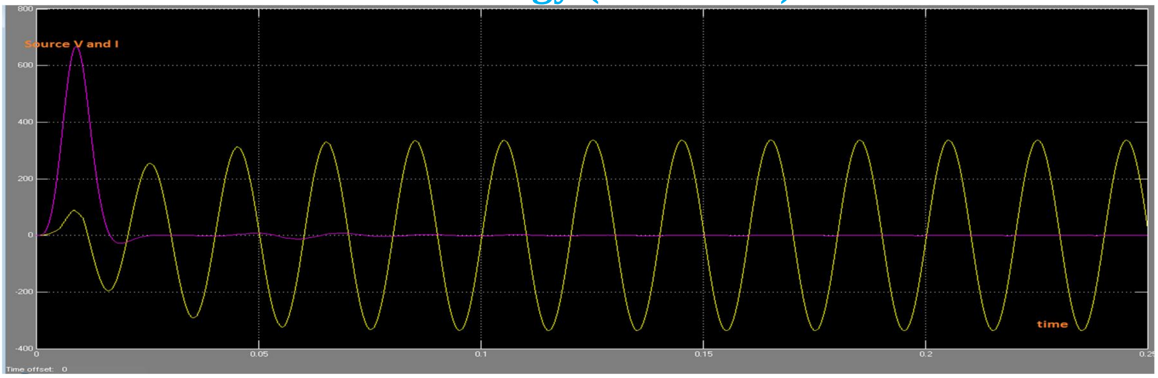

Fig.7: PF without DSTATCOM

Following results shows adjustable speed drive simulation results with DSTATCOM. Figure.8represents the source voltage of a 3-phase system with DSTATCOM. The Figure.9 represents PF improvement with DSATCOM. Figure. 10 represents Source current with DSTATCOM. Figure.11 represents THD of source current with DSTATCOM. The Figure.12 representsStator Currents, Motor Speed and Torque. The Figure.13 Output wave forms

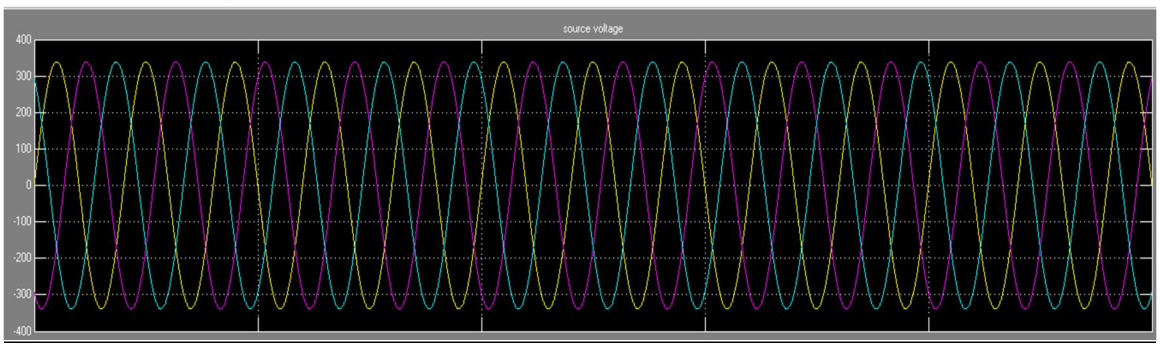

Fig.8: Source voltage with DSTATCOM

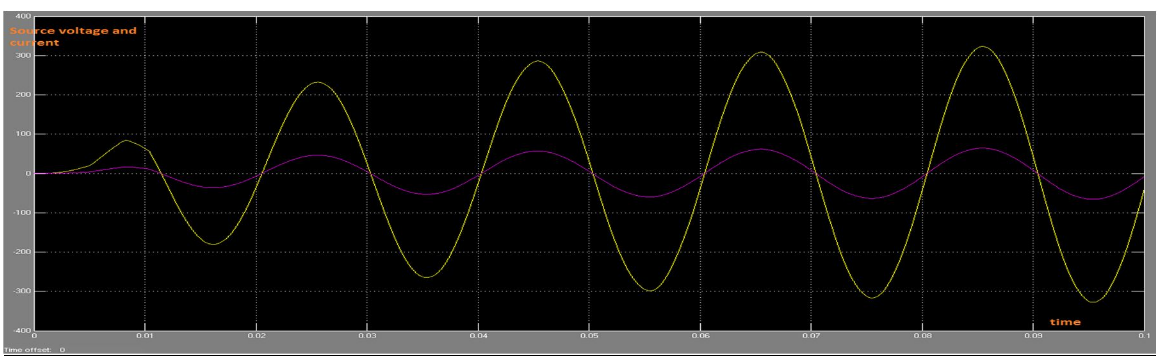

Fig.9: PF improvement with DSATCOM

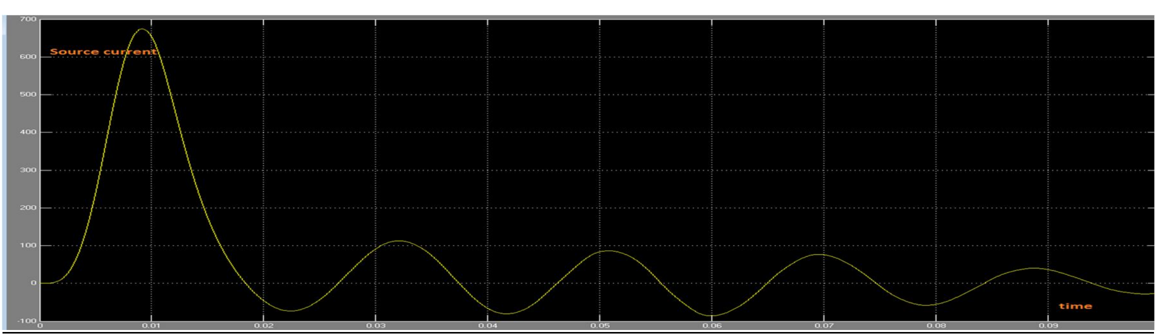

Fig.10: Source current with DSTATCOM

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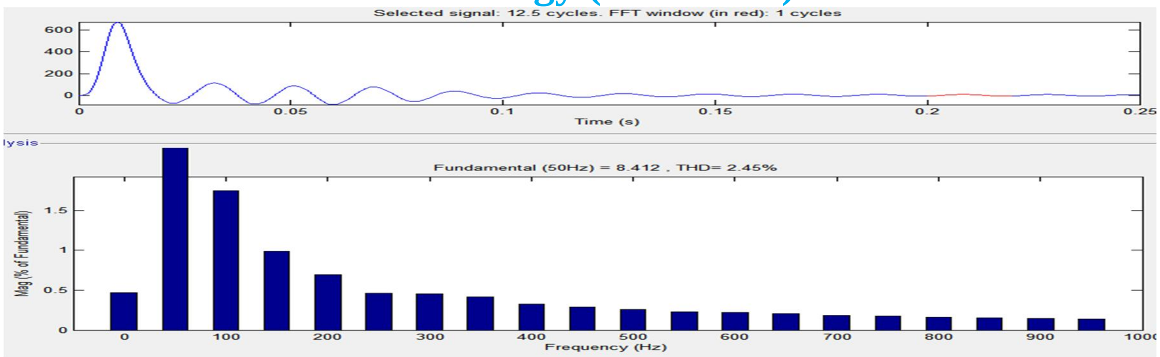

Fig.11: THD of source current with DSTATCOM

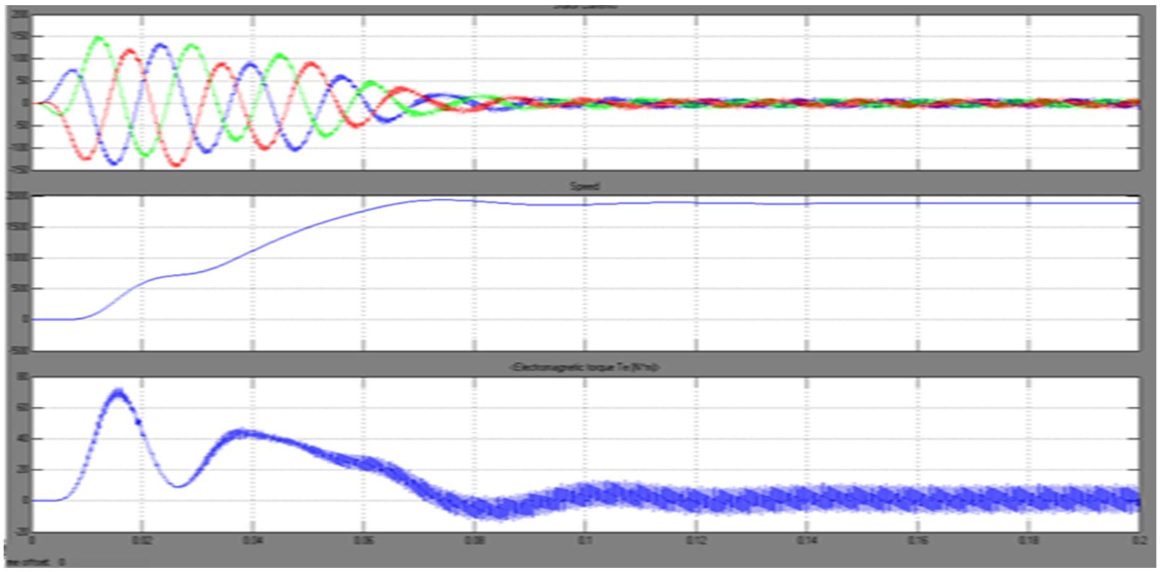

Fig.12: Stator Currents, Motor Speed and Torque

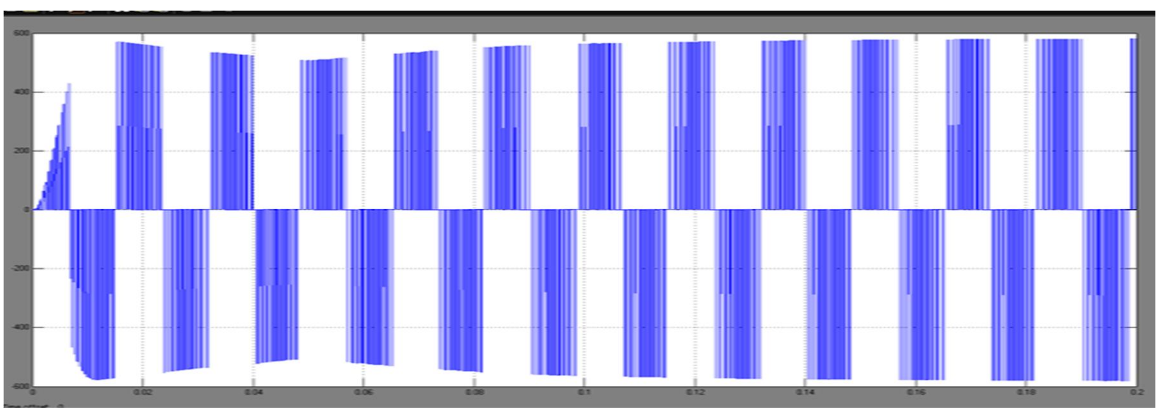

Fig.13: Output wave forms

IV. CONCLUSIONS

The application of DSTATCOM as a compensator has been demonstrated with adjustable speed drive. Models have been developed for an adjustable speed drive system feeding a 3Hp induction motor. It is observed that the content of harmonics injected by ASD is quite large. This harmonic injection in the neighbouring loads can create problems. DSTATCOM in the form of a 3-leg VSI bridge has been modelled and controlled for harmonic reduction. Simulation analysis of the load currents with these nonlinear loads has been presented without / with DSTATCOM. The solution suggested in the form of DSTATCOM is better than a number of passive filters providing selective compensation. It is concluded that such a compensator can be effectively designed to meet the IEEE-519 standard for regulating the level of harmonics below 5% limit with speed drives.

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