HID Lamps Dimming Possibilities in the Africa's Lighting Systems Context

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Abstract— **HID lamps are wide used in lighting systems, also in indoor and outdoor applications. The ballasts necessary for their normal operation could be magnetic or electronic and in the last decade we assist to a debate on which is a better option, the dimming capabilities being one of the most claimed advantages of the electronic ballasts. But, in the last years, several lower cost solutions for getting dimmability with magnetic ballasts have been reconsidered. In this paper, the possibility to dim lamps trough the classical voltage amplitude modulation by means an autotransformer is explored. This solution can be cheaper, robust and most suited for the low budget Africa's lighting systems. To understand the context, two lighting systems from Antananarivo, capital of Madagascar, and Dakar, capital of Senegal, have been depicted. Experimental tests have been performed on 250 W HID lamps, a High Pressure Sodium (HPS) and a Metal Halide (MH), operated by Very Low Loss magnetic ballast. The range of the voltage modulation has been from 160 V to 250 V and the power consumption, the light output and the harmonics content have been recorded. The energy saving per lamp by dimming to 160V is about 50 to 55% for the considered lamps.**

I. Introduction

The city's public lighting is dominated presently by High Intensity Discharge (HID) lamps and the necessity to avoid high and unnecessary electricity consumption led to the exploring of the dimming capabilities for the existent lighting installations. Although the LED sources are attractive because their excellent features, HID sources remain important for many lighting applications - especially outdoor (street lighting, parking etc.) but also indoor (commercial or industrial applications) - being characterized by one of the highest lighting efficiency among the light sources. Public lighting systems are a major source of electricity consumption, in present 3.19% of global electricity generation is used for lighting [1].

Some measures are recommended for decreasing electrical energy consumption afferent to the public lighting:

1) Reduction of the luminance level (dimming) on the duration of the hours with reduced traffic, through the decrease of the feeding voltage of the lamps;

2) Street classification compliant with international standards and the establishment of the light technical parameters based on this classification;

3) Proposal to adopt a special price for the electric energy destined for public lighting, due to the consumption on duration of the night [2].

Improving the public lighting efficiency require also modern adaptive or dynamic lighting control intelligent system when light levels are adjusted in real time based on predefined parameters. Although the structures of intelligent road lighting control systems are similar, the control parameters and control strategies are variable, depending on the specific case, budget and decision makers. Time-schedule-based step dimming is a commonly used control strategy nowadays in street lighting control system. The lamp light output is controlled centrally and can be adjusted to two up to four dimming levels according to preset time schedules [1].

There are different possibilities to control the lighting level: the use of electronic ballasts, the use of dual-power series inductive type ballasts, and the use of regulators and stabilizers in the head of the line. The choice of the lighting level control system will be determined by several factors including the voltage variation of the lamp, the status of the main supply of the lamp, the lamp type or the number of hours of operation. Most of the papers explore the dimming control of HID lamps and focus on the progress and perfection of the electronic ballasts [3, 4].

Unfortunately, they are either too expensive or too complicate to the practical use, especially in the low budget Africa's countries. Environmentally, the use of electronic ballasts (with a relative low duty time of 10 years) for large public lighting systems will generate large toxic electronic waste [5, 6].

This paper explores a simple solution of using a central dimming system, which controls the HID lamps consumption and lighting output through the network voltage modulation. The central dimming technology includes autotransformers, power electronic systems or combinations of them.

Reference [7] proposes a fully electromagnetic regulator and stabilizer installed in header line that assures a proportional variation of the luminous flux, the voltage and the power of the lamps (a reduction of 50% of output light implies a reduction of approximately 40% of the power consumed by the facility).

Considering the Africa's lighting systems, this work reevaluates the possibility of dimming the conventional magnetic-ballast-driven lighting system by the voltage amplitude modulation provided by an autotransformer. Dimming tests have been done with market-available HPS and MH lamps, powered by corresponding VLL magnetic ballast [8, 9]. Dimming characteristics have been recorded. The solution has been compared in terms of costs with an individual accessory of dimming lamp-ballast.

II. HID Lighting

The compact design of fixtures, attractive color characteristics, and high lumen efficacy of HID lighting make it an appealing option for industry applications. Three main types of HID lighting have been usually used: mercury vapour, HPS, and MH lamp. Mercury vapour lamps are no longer used in manufacturing facilities in a significant capacity. The other two types of lighting are the base on the public lighting [10].

The HID lamps are characterized by a long duty life and are operated by the ballast, a series element for the current limitation and discharge stabilization, which can be either electromagnetic or electronic. HID lamps typically require a warm-up period so they cannot be efficiently and instantaneously switched on and, when the supply falls for more than 0.2 sec., the lamps need a certain time for the reigniting process. The proper lighting of the public places requires usually a high power lamp, like 250W for individual lamps and 150W for dual lampposts. Thus, the electricity consumption in public lighting is dominant in the municipal budget of Africa's countries. As example, it has increased from 20% to 35% of the total municipal budget in Dakar Senegal, where the consumption is around 800GWh per month with 26000 luminous points [9]. The involved costs are always important.

The trend of using electronic ballasts to replace magnetic ballasts has prompted an increasingly problem of accumulation of large amount of nonbiodegradable and electronic wastes. Compared with magnetic ballasts which can last for over 30 years and are recyclable, electronic ballasts and the compact fluorescent lamps (CFLs) have short lifetimes due to the use of the electrolytic capacitors for providing the high DC voltage link in the electronic ballast designs. Thus, the following is the question that remains to be answered: Is it worthwhile to use electronic ballasts for large public lighting systems to reduce some power consumption for a few months to a few years and let them become nonbiodegradable and/or toxic electronic waste for thousands of years? This question is particularly valid with the emerging of low-loss magnetic ballasts and central dimmable systems for magnetic ballasts [11].

Apparently "electronic ballast is 10%...15% more energy efficient than electromagnetic ballast", but this affirmation is only correct at the full-power operating point when compared with the standard electromagnetic ballast. As Chung et al. showed, under most of the dimming ranges, the power loss of low-loss electromagnetic ballast is less than that of dimmable electronic ballast [12]. The advantages and disadvantages of electronic ballasts can be summarized as follows:

1) Advantages: dimmable, energy saving (up to 13%), increased life lamp (30%), no flickering effect, high efficiency, low audible noise, small size.

2) Disadvantages: relatively expensive, short lifetime (one to five years), relatively poor immunity against extreme weather conditions such as high humidity, wide temperature variation and lightning, not environmentally friendly (toxic and/or nonbiodegradable electronic waste that is not recyclable), no self-recovery feature, high maintenance and repair costs [13].

With this large inconvenient of electronic ballast it remains particularly valid the promising of Very-Low-Loss (VLL) magnetic ballasts and smart collective or individual dimmable systems for magnetic ballasts. The structure of the magnetic ballast system (consisting of ballast, a starter, and a power factor correction capacitor) is simple, robust, and reliable. It can be used even under hostile working environments and has a very long service life. The dual-power level ballasts have the drawback that act locally and need an adjustment control system, both on individual and general level, driving to high initial investment as well as high demanding maintenance requirements, being a complex and expensive solution [14].

III. Public Lighting System in Africa: Cases of Antananarivo and Dakar

In Africa, as in Madagascar and Senegal, most sources of electrical energy are thermal power plants, which are sources of highly polluting energy but they are easier to install and simple to control comparing to the other energy resources versus the load demand variation The cost of kWh of thermal energy fluctuates with the price of fuel. Moreover, fluctuations in the price of fuel currently make the system even difficult to manage, because of the inflation. To keep a stable value of kWh, the governments subsidize the cost of the energy. Even so, only about 24% of the people living in sub-Saharan Africa had access to electricity in the year 2000, electrical networks being limited mainly to the urban areas and still use an older installation [15]. In the rural areas only 2…5% of the population is supplied with electrical networks.

TABLE I.
Pubic Lighting Characteristics in Antananarivo

Lamp power (W)	Nature	Lampposts Distance (m)	Installation place	Command off/on
125	HPM	40 m	Path, boulevard	Electromecanical
160	Mix	50 m	Path, street	Electronic
250	Mix	60 m	Boulevard	Lumandar
250	HPM	70 m	Down town	Electronic
400	HPM	90 m	Rural town	Lumandar
150	HPS	-	Crossroads	Electronic
250	HPS	-	Boulevard crossroads	Electronic
400	HPS	-	Tunnel	Lumandar

In Antananarivo, the capital of Madagascar, the streets lighting are dominated by mercury lamp as HPM and Mixed Lamp (Mix). A number of about 15000 luminous points are used and only 2000 luminous points are equipped with ballasts. The lamps are mixed up in a line of a road light and the luminosity is not linear. The use of HPS lamp is restricted only in tunnels and in some crossroads. The downtown is equipped with high pressure mercury lamp (HPM). Table I shows the nature of lamps and the specification of public lighting in Antananarivo [16].

Because of the non-existent or a low budget of public lighting in Madagascar, the older installation is dominated by mercury lamps. Often, when a ballast get defects, it is replaced (together with the associated lamp) by simply lamps with incorporated ballasts as Mix lamps or compact fluorescent lamps (CFL). Thus, the numbers of the used HPM and HPS lamps, which need magnetic or electronic ballasts, decreases in time. Thus, the uses of HPM and HPS lamps supplied by magnetic ballast are reducing in time. The possibility of dimming is possible only for the HID lamps but not for the Mix lamps. Table II shows the comparison of luminosity characteristic and price of 250W lamp power used in Antananarivo [16, 17].

TABLE II.
CHARACTERISTIC AND PRICE OF LAMPS IN USE ANTANANARIVO

Lamps	Type	Lumen flux (lm)	Efficacy (lm/W)	Price (EUR)
Mix	Mix	5500	22	37.09
HPM	HPM-N	12700	50.8	20.36
HPS	SON-T +	33000	132	48.87

Mix lamps can be installed directly as an incandescent lamp without ballast. The color rendering is good, Ra =65 but his lifetime is short, of about 2000…7000 hours; it is a mercury lamp with an incandescent filament connected in series with an arc tube which acts as a ballast [11-17].

Moreover, the use of Mix lamp gets a lower efficacy and increases consumption. As seen in table II, one HPS lamp can replace six Mix lamps on the same power, of 250W. The use of HPS lamps is recommended to improve the system energy efficiency instead of the mercury lamps. The increasing number of luminary with Mix lamp is not interesting than replacing in the existent luminary the HPM lamps with HPS lamps.

Dakar, the capital of Senegal, (a city mostly developed in West Africa), has 26000 luminous points in its public lighting system [4]. Lamps HPS 250W for individual lampposts and 150W for dual lampposts are the most used, and a part of residence and some tourist places is equipped by MH lamp 150W. Those 26000 luminous points are divided in two: modern grid, with an underground cable and luminary compact on iron of about 14000 luminous points, and a standard grid with cable in suspension and post on wood or concrete (12000 luminous points). The monthly consumption of public lighting in Dakar municipality is about 750 to 800 GWh. The public lighting characteristic is shown in Table III [9]. The technique of dimming lamps is not exploited yet, and lamps stay in full power all the time of use. Ferromagnetic ballast only is used to supply the public lighting system.

TABLE III.
PUBIC LIGHTING CHARACTERISTICS IN DAKAR

Lamp power (W)	Nature	Lampposts Distance (m)	Installation place	Command off/on
70	HPS	25	Path, residence	Electronic
100	HPS, LPS	30	Road, tunnel	Electronic
125	HPS	30	Small boulevard, Area down	Electronic
150	HPS, MH	45	Boulevard, residence, tourist area	Electronic
250	HPS	45	Large boulevard, highway	Electronic

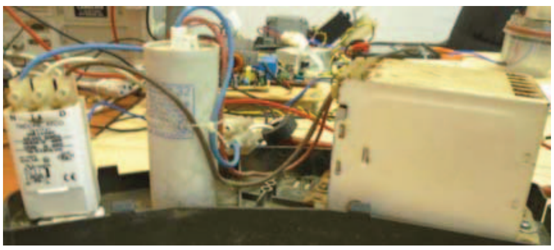

Fig. 1. Sample public lighting component in Dakar.

Fig. 1 shows sample public lighting component composed by a starter, a capacitor to compensate power factor and ballast magnetic which supplies lamp HPS 250 W installed in Dakar Boulevard. Besides the 26000 lamps light points, several hundred of LED solar street lights 48W are used in Dakar for about 2 years [9].

IV. DIMMING CAPABILITIES OF MAGNETIC BALLASTS

For a long period, the magnetic ballasts were considered a reliable and cost-efficient solution even they have two major drawbacks: low energetic efficiency and no dimming capability. HID lamps are negative impedance device. This means that unless controlled, the current would continue to increase, causing the lamp to fail almost instantly after starting. The negative impedance characteristics require a current controlling or limiting device, that is, the ballast to give the power supply to the HID lamp. The ballast serves three functions. It provides the proper starting voltage to establish the arc. Second, it supplies the proper voltage to operate the lamp. Third, the ballast limits the lamp current to a level prescribed by the lamp manufacturer for the particular type of lamp being used. Ballasts must always be matched to the particular lamp type, wattage, and line voltage being used [18].

The electronic ballasts offer low energetic losses and excellent dimming features, but for a lower reliability and higher cost. Also, acoustic resonances are a main concern for design the electronic ballast. Thus, the occurrence of acoustic resonances at high frequency can be considered as a limitation for a wide and reliable application of high frequency electronic ballasts for HID lamps [14-19].

Some tests on road lighting dimming system on six-line highway reveal that a 20% lighting level was sufficient for light traffic at night without negative consequences. Also it states that driving is comfortable under light traffic conditions even when the lighting level is reduced. Light level details are shown in Table IV [20].

The possibilities to dim the light output and the consumed power in the case of magnetic ballasts are resumed in Table V. Automatic Dimmer with sensor, extinction and ignition auxiliary kits can be installed with magnetic ballast to control the light.

TABLE IV.
LIGHTING LEVEL SETTINGS IN A HIGHWAY STUDY

Light level requires	Conditions
200%	Exceptional conditions such as fog or a combination of rain, high traffic density and accidents.
100%	High traffic density
20%	Low traffic density late at night

TABLE V.
INDIVIDUAL GRADING OF MAGNETIC BALLAST

Dimming method	Main operations	Compatibility
Triac: Phase angle control	Upstream of the ballast	70W to 400W : Magnetic Ballast
Ballast with two power sockets (BFM) Amplitude modulation	Two hook-ups at normal and reduced power.	Magnetic ballast + power switch 70W to 400W
Regulation by anti harmonic booster transformer Amplitude modulation	Voltage Regulation for ballast output downstream to maintain the sinusoid	Magnetic and electronic ballast 70 to 400W

The method of graduation practically consists in varying the absorbed power by cutting phase of main voltage with a device performs by a Triac circuit [21]. This method is not incompatible with the electronic ballast (the electronic ballast compensates the variation in voltage by phase modulation), and seems to be more convenient and cheaper for the magnetic ballasts, a multi-level dimming being possible [14-22].

The second method is to use two-level power ballast BFM (Ballast Ferromagnetic Multi-watt) such as constant-wattage autotransformer (CWA) or constant-wattage isolated transformer (CWI) ballast that operates only between two or three powers that are the normal and reduced powers. This system is always accompanied by a power switch [14]. With dimmable electronic ballast, the maximum scale value can reach 60% of rated power [21-23].

According to the Table VI, the price of the luminaries accessories for a HPS lamp driven by a magnetic ballast (lamp, ballast, igniter) looks promising (~115 to 160 €), while the price in the case of a dimmable electronic ballast for the same lamp is three times higher (~397 €) [17].

TABLE VI.
THE PRICE OF ACCESSORIES IN PUBLIC LIGHTING IN 2014

Philips HT price (€)				
B1 magnetic ballast SON/ CDO/CDM150W		B1 bi-power mag. Ballast (150/100) MK4 –BSN SON/CDO	Igniter (MK4/ SON)	Dimmable electronic ballast (HID- Dyna Vision Xtreme PROG)
SHP	64.49	67.64	33.26	396.90
HIM				
Accessories dimming (HT €)				
Dimmer (Proposed device)			Switch DALI (Tridonic)	
61			13,67	

For a public lighting system with thousands of luminous points, to replace all the magnetic ballasts with dimmable electronic ballasts is not necessarily a solution. This improvement needs a high investment costs and the advantage of the lower electricity consumption is not enough to get a convenient recovery time because electronic ballasts lifetime is not long enough (about 10 years) [19-24]. Table VII shows this difference [17]. The voltage line variation can be used for getting dimming when HID lamps are operated by magnetic ballasts.

TABLE VII.
A COMPARISON OF PHILIPS HID BALLASTS

Criteria	Electronic Dimming ballast	Magnetic ballast + Igniter
Dimming	Individual	Individual
Cost of dimming individual (€ HT)	397	159 115 (with BFM)
Warranty (yrs)	8	8
Lifetime of ballast	< 10 years	> 35 years
Maintenance	Difficult	Easy
Installation	Necessity of an additional line control	Intelligent, Power line
Environment	toxic not recyclable	Recyclable
Loss maximum dimming (%)	>5(rated power)	<1(rated power)

To vary the power of the lamps, different methods have been proposed (Table I). The voltage variation consists in a linear variation of the amplitude of the voltage waveform, without deformation caused by the harmonics increased presence. In a limited range of variation, the active power will vary according to its proportionality with the square of the voltage as in (1) [6, 7]:

$$P = UI \cos\varphi = U \frac{U}{Z} \cos\varphi = \frac{U^2}{Z} \cos\varphi \qquad (1)$$

V. EXPERIMENTAL TESTS

For an experimental verification, Philips B1-class 250W HID ballast (very low loss ~ 4%) has been chosen to drive two types of 250W HID lamps, commonly used in the outdoor lighting: high pressure sodium lamp (HPS) (in this tests Philips 250 W SON-T) and metal halide lamp (MH) (in this tests OSRAM HQI Germany).

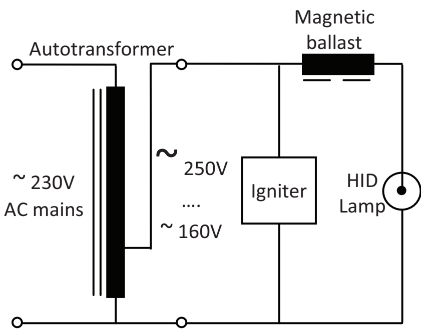

Fig. 2. Experimental diagram.

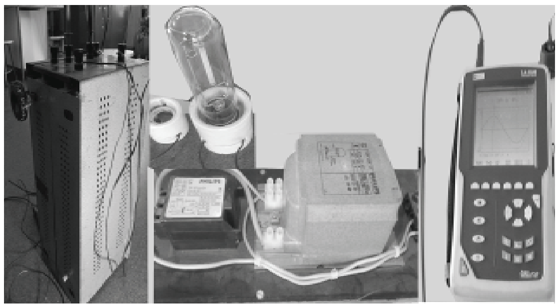

Fig. 3. View of the test bench.

The voltage variation done by modulating the amplitude has been produced by a central autotransformer (Fig. 2, Fig. 3) in the range between 160V to 250V. The measurements have been performed successively connecting the two lamps to the same ballast, keeping the following data: illumination, circuit consumed power, total harmonic distortion, current crest factor, efficient current comparison (IRMS) of the network and ballast output characteristics analysis for HPS lamp. The power loses in autotransformer have not been recorded.

A. *Illuminance deppending on the dimmed voltage*

The illumination produced by the lamps has been measured by means a luxmeter placed in a fixed position at 6.5 m horizontal distance from the lamp, and 30 cm above the floor. Because the room was not completely dark, the illumination level E_r has been calculated as a resultant extracting the background illumination E_{back} (measured with the lamp off before each test) from the values get with the lamp on (E_m)

$$E_r = E_m - E_{back} \,. \tag{2}$$

Due to the low ionization energy of sodium, for the HPS lamp it was obtained an illumination as low as 12 lx when the supplying voltage decreased to 160V. On the opposite, at 250 V, the lamp can reach the maximum illumination value of about 130 lx (Fig. 4).

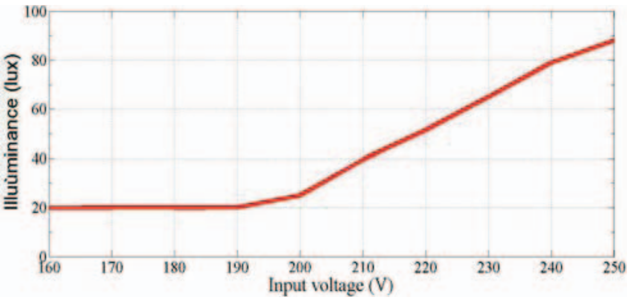

Fig. 4. Light output of the 250W MH lamp.

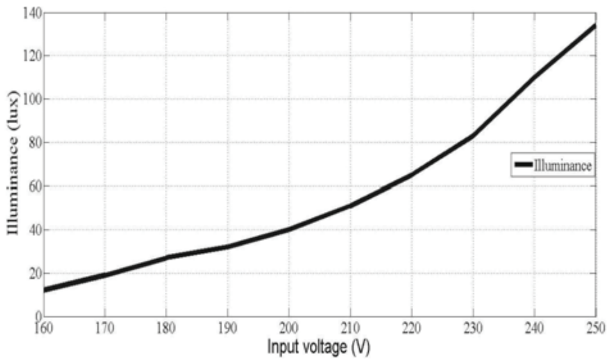

Fig. 5. Light output of the 250W HPS lamp.

An important feature of the MH lamps is the light color, a polychromatic white, while the efficient HPS lamps spread out a yellow light. The tests on MH lamp show that illumination keeps it constant at a value of 20 lx while the supplying voltage ranges between 160 and 190V (Fig. 5). It seems that the proportion of ionized metal remains constant with the decreasing temperature of the plasma. To higher supplying voltages values, the brightness increases, but the maximum get illumination value was 90 lx for the operation at 250V.

B. *Lamp Power versus Illuminance*

As presented in Fig. 4 and Fig. 5, the shape of both curves is similar; the dimming procedure describing an almost linear trend of the power. For the HPS lamp, the maximum energy savings achieved can be up to 55% for a 250W lamp, and the rated power is obtained at the voltage of 230V. For MH lamp, it can be up to 52% at the minimum value of the voltage. The presence of flicker and strobe lights are not found during the dimming phase. Lamp power means the power consumed by the HID lamp only and does not include loses in the VLL ballast and the autotransformer system. Figs. 6 and 7 present the variation of the lamp power and illumination of the tested lamps.

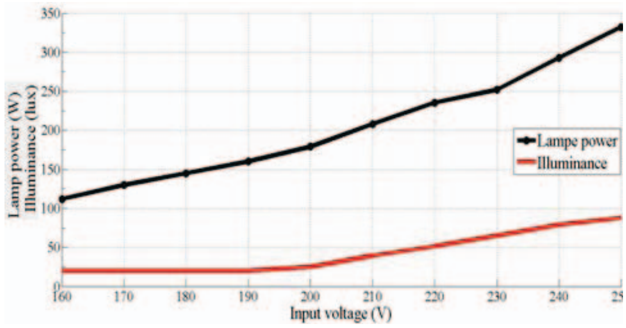

Fig. 6. Lamp power and light output response of the 250W MH lamp.

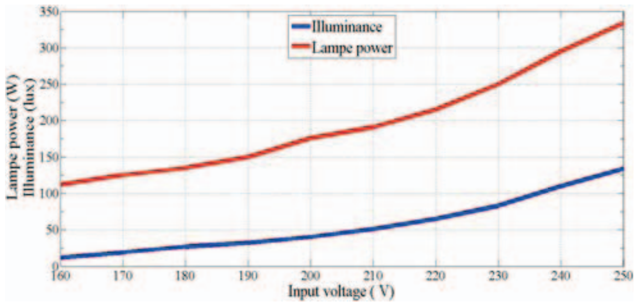

Fig. 7. Lamp power and light output response of the 250W MH lamp.

The extreme experimental values are given in Table VIII. The HID lamps are difficult to dim because of the negative impedance of these lamps. Dimming process decreases the efficacy of the lamp due to the temperature variation of the plasmatic discharge gas. Thus, HPS lamp appears to be easier to dim than MH lamp [25].

However, sodium lamp is sensitive to the voltage variation of the autotransformer. On the contrary, MH lamp appears to be more stable for underrated voltage, the variation of lamp output being slow. The MH lamp light output is constant for about 30V voltage variation, from 190V to 160V. Dimming MH lamp is satisfactory in the stability of the lamp output with minimum power. However, the efficiency is low. The present reduction of 70 V is calculated from the main voltage of 230 V to the minimum voltage of 160 V.

TABLE VIII.
EXTREME EXPERIMENTAL VALUES

Lamp type		HPS		MH	
		units	[%]	units	[%]
Rated lamp power (W)		250	100	250	100
250V	Lamp power (W)	334	134	332	133
	Illumination (lx)	130	159	88	135
230V	Lamp power (W)	250	100	252	101
	Illumination (lx)	82	100	65	100
160V	Lamp power (W)	112	45	112	45
	Illumination (lx)	12	15	20	31

TABLE IX.
LAMPS WORKING POINT IN 160V INPUT VOLTAGE

Lamp	Optimal ΔU (V)	Luminance Reduction (%)	Energy saving (%)
High Pressure Sodium	70	85.54	55.2
Metal Halide	70	69.23	52.72

The measurements were made on upstream of the ballast power supply. Table IX shows a great reduction in consumption, around 55% for HPS lamps and 53% for MH lamps. In term of light output, a strong depreciation of about 85.54% was observed for HPS lamp, available light being only of 14.45%. Thus, to keep the minimum luminosity for about 20% according [20], the minimum voltage dimming for HPS lamp should stop at 170 V, the HPS lamp being more sensitive to dimmability.

However, MH lamps' luminosity decreased with about 69%. At 160 V, the available light is still about 31%. Arguably, the proposed energy saving is more efficient with MH lamp.

C. The total harmonic distortion of current evolution and the Current Crest Factor (CCF)

The current total harmonic distortions (THDI) of ballast input voltage have been measured for both lamps and results are showed in Fig. 8. It can be interpreted as follow:

1) The THDI increases with the mains voltage (160V-250V). THDI varies from 6.78% to 14.7% for the HPS lamp and from 7.23% to 15% for the MH lamp;

2) At the rated voltage of AC mains (230V, 50 Hz), the THDI is 12.07% for the HPS lamp and 10.27% for the HM lamp. The impedance for nonlinearity of HPS lamp is higher than MH lamp. The biggest value of about 15% is obtained in overrated voltage 250V; In fact, supplying lamps over the mains voltage 230 V is not required. Lamps dissipate more power than its rated power, lamp lifetime decreases by overrated voltage, increases consumption and harmonic disturbance;

3) For HPS lamp, the value of THDI is almost constant from 160V to 190V as the impedance of this lamp is higher than the MH lamp. The plasma characteristic of MH lamp is less stable than the HPS lamp plasma discharge, and for that the THDI is not constant for under voltage (160V – 190V).

The CCF varies from 1.47 to 1.68 (Fig. 9) for the HID lamps, which are considered less than the maximum CCF rated for HID lamps (1.8 for MH and 2 for HPS) [14]. Thus, these measured values are normal for the electric network. Moreover, the technique of dimming with the autotransformer is favourable for a good value of CCF.

The I_{RMS} of two HID lamps (Fig. 10) are related and parallel (2A…3.3A for HPS lamps; 1.9A…3.3A for MH lamp), and the difference is about 0.1A…0.2 A. HPS lamp value is higher from 160 V to 230 V as the impedance of this lamp is higher than the MH lamp. The plasma characteristic of MH lamp is more stable than the HPS lamp plasma discharge, for that the light output is constant for the under supply voltage (160 V…190 V).

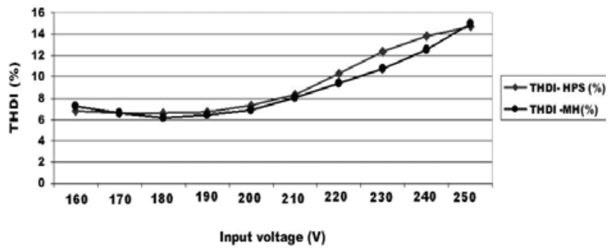

Fig. 8. TDHI for the both tested lamps.

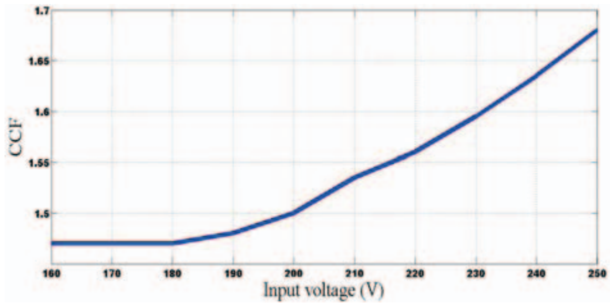

Fig. 9. CCF of the Main supply.

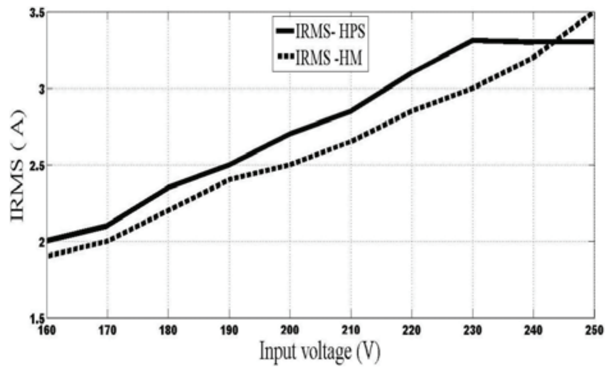

Fig. 10. IRMS of the Network.

D. HPS lamp ballast response analysis for ignition - warm-up – stabilization time.

In this part of work an analysis of HPS lamps ballast characteristic is performed. Fig 11 shows the current-voltage curve for 250 W HPS lamp measured with magnetic ballast. The measurement is recorded from the ignition time to the stabilization of the lamps for about 15 minutes. It is revealed that supply voltage increased from the ignition and it is stabilized near 150 V for its running state, but the current decreased from 3.75 A to 2.54 A. The character of the magnetic ballast in terms of power supply and stabilization of current for a load with negative impedance is observed.

The experiment noted that the warm-up time for the lamp is 25 seconds. Fig.12 shows the reduction of intensity of ballast current after 25 seconds of lamp ignition. HPS lamp checks the status of current limiting with a current almost constant before progressively declining. 250W HPS lamp reached its running state beyond 450 seconds.

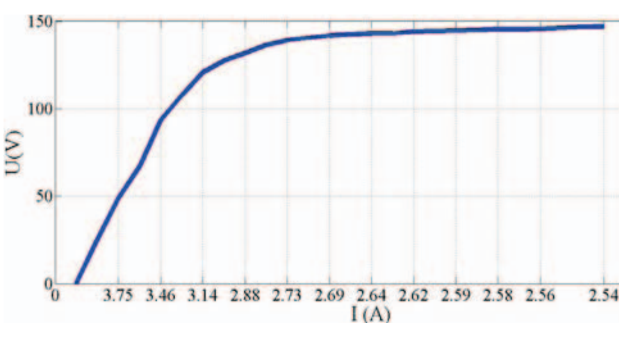

Fig. 11. Ballast Characteristics, U = f (I) for 15 minutes of 250W HPS lamp power supply.

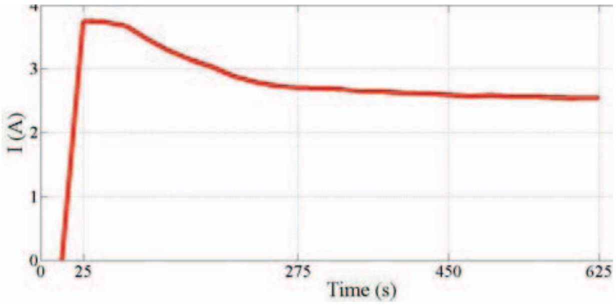

Fig. 12. Ballast current evolution for 15 minutes of 250W HPS lamp power supply.

VI. Conclusion

This paper analyses the possibility to dim lamps trough the classical voltage amplitude modulation by means of an autotransformer. This solution can be cheaper, robust and most suited for the low budget Africa's lighting systems.

Previously, a regard on HID lighting is presented followed by the details of the public lighting system in Africa: Antananarivo, Madagascar and Dakar, Senegal.

Some characteristics of HID lamps have been investigated while varying the supplying voltage network by an autotransformer. Experimental tests have been performed on 250W HID lamps, a High Pressure Sodium (HPS) and a Metal Halide (MH), operated by Very-Low-Loss magnetic ballast. Experimental results show that HPS lamp is sensitive to the voltage diminution from 250V to 160V, and is followed by a relative linear trend in the light output decreasing. For the MH lamp, between 190V and 160 V, the lighting output remains practically constant. Both lamps proved good ignition and stable operation in the explored voltage range.

The analyzed dimming method is a practical and efficient way for the present wide used magnetic ballast for HID lamps. It involves a good compatibility with the present installed HID lamps, simplicity and lower costs than using the individual electronic ballasts. On the other side, this dimming method involves increased values of THD and CCF. While CCF remains always in requested limits, for limiting the high values of THD a global harmonic filter could be necessary. A global harmonic filter could be necessary. Moreover, the reactive power in the network increases with the use of central dimming based on a large transformer component device.

These drawbacks can be eliminated by the individual dimming electronic devices, but the options for the last ones needs especially large initial investments and qualified specialists that are not always available in Africa's countries.

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