UNIVERSITI PUTRA MALAYSIA

IMPROVEMENTS IN DESIGN OF LOCAL FLUORESCENT ELECTRONIC BALLASTS IN COMPLIANCE WITH THE RELATED LOCAL AND INTERNATIONAL STANDARDS

ZULKEFLI BIN YAACOB

IMPROVEMENTS IN DESIGN OF LOCAL FLUORESCENT ELECTRONIC BALLASTS IN COMPLIANCE WITH THE RELATED LOCAL AND INTERNATIONAL STANDARDS

By

ZULKEFLI BIN YAACOB

Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Science in the Faculty of Engineering Universiti Putra Malaysia

February 2001

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement of the degree of Master of Science.

IMPROVEMENTS IN DESIGN OF LOCAL FLUORESCENT ELECTRONIC BALLASTS IN COMPLIANCE WITH THE RELATED LOCAL AND INTERNATIONAL STANDARDS

By

ZULKEFLI BIN YAACOB

February 2001

Chairman: **Ir. Dr. Md. Yusof Ismail**

Faculty: **Engineering**

The fluorescent electronic ballast has been in the market for a long time but has not created any great impact in the illumination industry due to its high initial cost of investment compared to the conventional magnetic ballast. With the advancement in power electronics and utilization of power semiconductor which is available commercially today, it is now possible to implement almost every type of desired conversion of current, voltage or frequency and availability of electronic components with higher power ratings. Thus, it is now possible to manufacture an economically priced, light weight, lower watt-loss and high quality with maximum performance electronic ballast which is compatible with all types of fluorescent luminaries.

This study is undertaken to improve the design of existing locally manufactured electronic ballasts. The study indicated that many of these commercial electronic ballasts only have partial or minimum compliance requirements or none at all to the related local and international standards, namely MS IEC 928, MS IEC 929 and EMC requirements as stipulated by SIRIM Berhad. From a survey on nine different ballast manufacturers, only seven manufacturers conducted two tests on MS IEC 928 and MS IEC 929 and only two manufacturers conducted a complete list of tests to ascertain whether their product comply with the related local and international standards. Since electronic ballast is listed as one of the electrical controlled items by the Department of Electricity and Gas Supply of Malaysia (DEGSM), it is crucial that the EMC test be imposed prior to ballast approval.

A directive was issued by the Malaysian government on the 3rd of July 1998 to implement energy conservation and to promote the use of energy efficient equipment specifically on lighting luminaries and lighting control systems. DEGSM noted the limitations of fluorescent ballast watt-loss hence, this study is undertaken to meet the implementation of energy conservation regulations/act in the near future.

The study discussed the advantages and disadvantages of electronic ballasts, their operation and performance characteristics and problems encountered during their normal operations, for instance, surges, starting current, power factor, watt-loss.

ambient temperature and environmental effects, lamp/ballast premature failures, harmonics and electromagnetic (EM) disturbances, efficiency and dimming.

Various samples of electronic ballast were collected and tested for compliances with local and international standards. It was found that many samples failed the tests on total harmonic distortion (THD) which exceeded the 25% limit.

From the test data collected on the study, the findings from the analysis on the operation, performance, design and construction of the typical electronic ballast were utilised in the construction of two improved versions of electronic ballast prototypes. The two improved versions were retested and both passed all the tests conducted on them with better results.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

PEMBAIKAN DALAM REKA BENTUK BALLAST ELEKTRONIK PENDAFLUOR TEMPATAN DI DALAM MEMENUHI PIAWAI-PIAWAI TEMPATAN DAN ANTARABANGSA YANG BERKAITAN

Oleh

ZULKEFLI BIN YAACOB

Februari 2001

Pengerusi: **Ir. Dr. Md. Yusof Ismail**

Fakulti: **Kejuruteraan**

Ballast elektronik bagi kelengkapan lampu pendafluor telah lama berada di dalam pasaran tetapi tidak dapat memberi sebarang impak yang ketara di dalam industri pencahayaan disebabkan oleh kos pelaburan awal yang agak tinggi jika dibandingkan dengan ballast konvensional jenis magnetik. Dengan kemajuan di dalam bidang elektronik kuasa dan penggunaan semikonduktor kuasa secara kommersil yang terdapat sekarang ini, ianya berupaya untuk melaksanakan hampir setiap jenis penukaran yang diinginkan bagi arus, voltan atau frekuensi dan kedapatannya komponen-komponen elektronik yang berkadaran kuasa tinggi. Maka dengan itu, buat masa ini, adalah berkemungkinan besar untuk menghasilkan ballast elektronik pada kos yang lebih ekonomik, ringan, berkehilangan watt rendah dan berkualiti tinggi pada perlaksanaan yang maksima bersesuaian dengan semua jenis kelengkapan lampu pendafluor.

Kajian ini adalah bertujuan untuk memperbaiki reka bentuk bagi ballast elektronik buatan tempatan sedia ada. Kajian menunjukkan bahawa kebanyakan ballast elektronik kommersil tidak mempunyai, hanya mempunyai sebahagian atau pematuhan minima ke atas keperluan berdasarkan piawai-piawai tempatan dan antarabangsa berkaitan saperti MS IEC 928, MS IEC 929 dan keperluan bagi kesesuaian elektromagnetik (EMC) sapertimana yang diperlukan oleh SIRIM Berhad. Daripada kajian yang telah dibuat ke atas 17 contoh yang dikumpulkan daripada sembilan pengeluar ballast elektronik yang berlainan, hanya tujuh pengeluar telah melakukan dua ujian bagi MS IEC 928 dan MS IEC 929 dan hanya dua pengeluar sahaja telah melakukan senarai lengkap ujian. Ini adalah penting kerana ballast elektronik adalah merupakan salah satu daripada barangan elektrik terkawal oleh Jabatan Bekalan Elektrik dan Gas Malaysia (JBEGM).

Kajian ini juga membincangkan tentang kebaikan dan keburukan tentang ballast elektronik, ciri-ciri operasi dan perlaksanaan dan juga masalah-masalah yang dihadapi semasa ianya beroperasi secara normal saperti penerpaan, arus mula, faktor kuasa, kehilangan watt, suhu sekeliling dan kesan keatas alam sekitar, kegagalan pra-matang bagi lampu/ballast, harmonik dan kesan gangguan elektromagnetik (EM), kecekapan dan pemalapan.

Pelbagai contoh ballast elektronik telah dikumpulkan dan diuji-kaji bagi memastikan pematuhan berdasarkan kepada keperluan dan telah didapati bahawa kebanyakan contoh yang diuji telah gagal bagi ujian "Jumlah Herotan Harmonik"

yang mana melebihi tahap 25%. Daripada data ujian yang dikumpulkan di atas kajian yang telah dibuat, analisa ke atas operasi, perlaksanaan, reka bentuk dan pembinaan bagi ballast biasa telah digunakan di dalam pembinaan dua versi contoh sulung ballast elektronik yang telah diperbaiki. Ianya telah diuji sebagaimana yang telah dilakukan keatas contoh-contoh yang telah dikumpulkan di mana kedua-duanya telah didapati lulus kesemua ujian berkenaan dengan contoh sulung yang kedua telah memberikan keputusan yang lebih baik.

Pada bahagian akhir kajian, data-data telah terkumpul telah dijadualkan untuk perbincangan dan perbandingan secara keseluruhan dalam menentukan sama ada contoh-contoh dan contoh sulung tersebut telah dapat memenuhi keperluan piawai-piawai berkenaan secara sepenuhnya atau tidak. Kesimpulan ke atas kajian kemudiannya telah dibuat. Penyelidikan lanjut dan perakuan telah dicadangkan berdasarkan kepada pendekatan reka bentuk baru, topologi-topologi dan teknik-teknik bagi pembinaan ballast elektronik dengan merujuk kepada penyelidikan yang dijalankan oleh berbagai pereka ballast elektronik.

ACKNOWLEDGEMENTS

A great effort went into the writing-up of this thesis which has been a great experience and an enrichment of knowledge. I would like to thank the following people and organisations for their contributions, without which this thesis could never have been completed.

First and always, my family. My ever-patient and supportive wife and two daughters, who have made many sacrifices during the duration and understood my need to further my studies. Thank you for your sincere emotional support, patience and understanding.

Thank you also to Ir. Dr. Md. Yusof Ismail, my supervisor and co-supervisors, Ir. Dr. Norman Mariun, Dr. Megat Hamdan Megat Ahmad and Dr. Mohd. Sapuan Salit for their tireless effort, guidance and generous recommendations and insights throughout the process of the writing-up of the thesis.

Thank you also to the electronic ballast manufacturers for their cooperation in allowing me to utilise their available technical resources and testing facilities during the research and for the analysis conducted on the thesis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC	Alternating Current
ANN	Artificial Neural Network
ANSI	American National Standards Institute
BSI	British Standard Institute
CBM	Certified Ballast Manufacturers Association
CCF	Current Crest Factor
CENELEC	European Committee for Electrotechnical Standardisation
CFL	Compact Fluorescent Lamp
CIC	Continuous Input Current
CISPR	International Special Committee on Radio Interference
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COP	Coefficient of Performance
CPPFC	Charge Pump Power Factor Correction
CS	Current Source
dB	Decibles
DC	Direct Current
DCM	Discontinuous Current Mode
DEGSM	The Department of Electricity and Gas Supply of Malaysia
DSM	Demand Side Management
ECM	Energy Centre of Malaysia (Pusat Tenaga Malaysia)
EEO	Energy Efficiency Officer
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EMF	Electromotive Force
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
ESR	Equivalent Series Resistance
EUT	Equipment Under Test

FCC	Federal Communications Commission
FLEB	Fluorescent Lamp with Electronic Ballast
GDP	Gross Domestic Product
GTO	Gate Turn-off
HVAC	Heating, Ventilating and Air-conditioning
HF	High Frequency
HID	High Intensity Discharge
HPS	High Pressure Sodium
HVDC	High Voltage Direct Current
IC	Integrated Circuit
IEC	International Electrotechnical Commission
IEEE	Institution of Electrical and Electronics Engineers
IES	Illuminating Engineers Society
IGBT	Insulated Gate Bipolar Transistor
IPP	Independent Power Producer
ISO	International Organisation for Standardisation
KPBE	Ketua Pengarah Bekalan Elektrik (Director General of Electricity Supply)
LISN	Line Impedance Simulation Network
LLS	Lembaga Letrik Sabah (Sabah Electricity Board)
LPW	Lumen per Watt
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MS	Malaysian Standard
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NLPIP	National Lighting Product Information Program
NTC	Negative Temperature Coefficient
PCB	Printed Circuit Board
PF	Power Factor
PFC	Power Factor Correction
PLC	Power Line Carrier

PSpice	A member of SPICE family of Circuit Simulators
PWD	Public Works Department
PWM	Pulse Width Modulation
RCCB	Residual Current Circuit Breaker
RF	Radio Frequency
RFI	Radio Frequency Interference
RLO	Relative Light Output
RMS	Root Mean Square
SCR	Silicon Control Rectifier
SESCO	Sarawak Electricity Supply Corporation
SIRIM	Standards and Industrial Research Institute of Malaysia
SO_2	Sulphur Dioxide
SPICE	Simulation Program with Integrated Circuit Emphasis
SLICE	Circuit simulator program developed by Harris Semiconductor
THD	Total Harmonic Distortion
TNB	Tenaga Nasional Berhad
UDCS	User Defined Controlled Source
UL	Underwriters Laboratories of USA
UPS	Uninterruptible Power Supply
US FDA	Food and Drug Administration of USA
UVLO	Under-voltage Lockout
VCO	Voltage Cut-out
VDC	DC Voltage Source
VS	Voltage Source

GLOSSARY OF TERMS

The following technical and lighting terminologies are frequently used with reference to the study. These are presented in alphabetical order and explained so that they are easy to understand. For a complete range of lighting terminology and precise definitions, please refer to the IES Lighting Handbook, 1981.

Active Filter	A filter which is switched in response to demand to attenuate or eliminate harmonic components and compensate for active power.
Advance, Firing Angle	The angle at which a thyristor starts conduction in advance of, and relative to, the instant when the thyristor forward voltage falls to zero in a converter. Used in relation to the inverting mode of operation.
Ambient temperature	The temperature of the general mass of air or cooling medium into which heat is finally transferred from a hot body.
Asymmetrical	Not uniform in characteristic or construction.
Avalanche	A chain reaction which occurs when minority carriers are accelerated by a high electric field, so liberating further carriers leading to a sharp increase in reverse current and breakdown.
Avalanche Diode	A diode which may temporarily be exposed to voltages of the order of the breakdown voltage.

Ballast	A device used with gaseous discharge lamps that provides necessary conditions to start and operate the lamps.
Ballast Factor	The percentage of light produced by a commercial ballast compared to a reference or standard ballast.
Bidirectional	Capable of current conduction in both directions, for example a triac.
Breakdown Voltage	The reverse voltage level at which the reverse current increases rapidly in a diode.
Bridge	Full-wave converter.
Chopping	A technique of rapidly switching on and off a source of voltage.
Clamping Voltage	Introduction of a voltage reference level to a pulsed or transient waveform to limit the peak value.
Closed-loop	A system in which information regarding the state of a controlled quantity is fed back to the controlling element.
Colour Rendering	An expression for the effect of a light source on the colour appearance of objects in comparison with their colour appearance under a reference light source.
Commutating Diode	A diode placed across a DC load to permit transfer of load current away from the source, and so allow the

	thyristors in the DC source to turn off. In addition to permitting commutation of the source thyristors, the diode will prevent reversal of the load voltage.
Conducting Angle	The angle over which a device conducts.
Conduction Loss	The energy dissipated within the device during the on-state conduction.
Constant-current Inverter	An inverter fed from a DC source with a large series inductor, so that over each inverter cycle the source current remains almost constant.
Constant-voltage Inverter	An inverter fed from a DC source with a large parallel capacitor, so that over each inverter cycle the source voltage remains almost constant.
Converter	A circuit which convert AC to DC or vise versa.
Critical Damping	Damping which gives most rapid transient response without overshoot or oscillation.
Damping	Extraction of energy from an oscillating system.
D.C Link	Intermediate DC stage between two systems of different frequency.
Delay, Firing Angle	The retarded angle at which a thyristor starts conducting relative to that instant when the thyristor