



شبكة المعلومات الجامعية

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ





شبكة المعلومات الجامعية



# شبكة المعلومات الجامعية

## التوثيق الالكتروني والميكرو فيلم

# جامعة عين شمس

التوثيق الالكتروني والميكرو فيلم

## قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها  
علي هذه الأفلام قد اعدت دون أية تغيرات



## يجب أن

تحفظ هذه الأفلام بعيداً عن الغبار

في درجة حرارة من 15 – 20 مئوية ورطوبة نسبية من 20-40 %

To be kept away from dust in dry cool place of  
15 – 25c and relative humidity 20-40 %



شبكة المعلومات الجامعية



# بعض الوثائق الأصلية تالفة



شبكة المعلومات الجامعية



بالرسالة صفحات  
لم ترد بالأصل

# **ENERGY SAVING VIA ELECTRONIC BALLAST**

By  
**Eng. ESSAM ABDEL GAYED MOHAMED HENDAWY**  
Electronics Research Institute

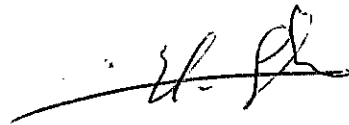
A Thesis Submitted to the Faculty of Engineering at Cairo University in  
Partial Fulfillment of the Requirements for the Degree of  
**MASTER OF SCIENCE**  
in  
**ELECTRICAL POWER AND MACHINES ENGINEERING**

Under the Supervision of

Prof. Dr. MOHAMED M. A. AZIZ  
Faculty of Engineering - Cairo University



Prof. Dr. FAEKA M.H. KHATER  
Electronics Research Institute



FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA , EGYPT  
MARCH 1998

B 1.710

3-4029-15

# **ENERGY SAVING VIA ELECTRONIC BALLAST**

By  
**Eng. ESSAM ABDEL GAYED MOHAMED HENDAWY**  
Electronics Research Institute

A Thesis Submitted to the Faculty of Engineering at Cairo University in  
Partial Fulfillment of the Requirements for the Degree of  
**MASTER OF SCIENCE**  
in  
**ELECTRICAL POWER AND MACHINES ENGINEERING**

Approved by the Examining Committee

Prof. Dr. Mohamed Mamdouh Abdel Aziz

Prof. Dr. Said Abd El-Monem Wahsh

Prof. Dr. Essam Abou Elzahab

FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA , EGYPT  
MARCH 1998





# CONTENTS

|                                              | Page |
|----------------------------------------------|------|
| <b>LIST OF TABLES</b>                        | iv   |
| <b>LIST OF FIGURES</b>                       | vi   |
| <b>LIST OF MAIN SYMBOLS AND ABBREVIATION</b> | xi   |
| <b>ACKNOWLEDGMENT</b>                        | xiii |
| <b>ABSTRACT</b>                              | xiv  |

|                                      |   |
|--------------------------------------|---|
| <b>1. INTRODUCTION</b>               | 1 |
| 1.1 General                          | 1 |
| 1.2 Illumination Definitions         | 1 |
| 1.2.1 Light Output                   | 1 |
| 1.2.2 Light Level                    | 2 |
| 1.2.3 Brightness                     | 2 |
| 1.2.4 Efficacy of The Lamp           | 2 |
| 1.3 Light Sources                    | 2 |
| 1.3.1 Incandescent Lamps             | 2 |
| 1.3.2 Fluorescent Lamps              | 3 |
| 1.3.3 High Intensity Discharge Lamps | 3 |
| 1.4 Fluorescent Ballasts             | 3 |
| 1.4.1 Magnetic Ballast               | 4 |
| 1.4.2 Electronic Ballast             | 4 |
| 1.5 Review of Literature             | 4 |
| 1.6 Scope of The Work                | 6 |

|                                                                           |    |
|---------------------------------------------------------------------------|----|
| <b>2. ELECTROMAGNETIC BALLAST AND<br/>CONVENTIONAL ELECTRONIC BALLAST</b> | 8  |
| 2.1 Introduction                                                          | 8  |
| 2.2 Electromagnetic Ballast                                               | 8  |
| 2.3 Conventional Electronic Ballast                                       | 9  |
| 2.4 Basics of Parallel Loaded Inverter for Electronic Ballast             | 9  |
| 2.5 Rectifier Stage                                                       | 12 |
| 2.6 Inverter Stage                                                        | 13 |
| 2.7 Load Simulation                                                       | 13 |
| 2.8 Simulation Results                                                    | 13 |

|                                                            |           |
|------------------------------------------------------------|-----------|
| 2.8.1 Supply Current and Voltage                           | 13        |
| 2.8.2 Switch Voltage and Switch Current                    | 16        |
| <b>3. HARMONIC CURRENT REDUCTION</b>                       | <b>18</b> |
| 3.1 Introduction                                           | 18        |
| 3.2 Harmonic Related Losses in Power Wiring                | 18        |
| 3.2.1 Cables                                               | 18        |
| 3.2.2 Transformers                                         | 19        |
| 3.3 Harmonic Reduction                                     | 19        |
| 3.3.1 Basic Rectifiers With Capacitor Filter               | 20        |
| 3.3.2 Series Inductor Filter                               | 20        |
| 3.3.3 Parallel-Connected Resonant Filter PCRF              | 21        |
| 3.3.4 Series Connected Resonant Filter SCRF                | 22        |
| 3.3.5 Boost Converter for Power Factor Correction          | 23        |
| <b>4. ANALYSIS AND DESIGN OF THE PROPOSED CIRCUIT</b>      | <b>24</b> |
| 4.1 Introduction                                           | 24        |
| 4.2 Circuit Configuration                                  | 24        |
| 4.3 Modes of Operation                                     | 25        |
| 4.3.1 On Period Equivalent circuit                         | 25        |
| 4.3.2 Off Period Equivalent circuit                        | 25        |
| 4.4 Circuit Analysis                                       | 26        |
| 4.5 Design of the proposed circuit                         | 32        |
| <b>5. THE POWER MOSFET</b>                                 | <b>36</b> |
| 5.1 Introduction                                           | 36        |
| 5.2 Features of MOSFET Transistor                          | 36        |
| 5.3 Driving the Power MOSFET Transistor                    | 37        |
| 5.3.1 Turn On and Turn Off Process                         | 38        |
| 5.3.2 Drive Circuit Operation                              | 39        |
| 5.4 Snubber Circuit for The MOSFET Protection              | 40        |
| 5.5 Pspice Model for MOSFET Transistor                     | 44        |
| <b>6. SIMULATION RESULTS</b>                               | <b>46</b> |
| 6.1 Pspice Model of The Fluorescent Lamp at High Frequency | 46        |

|                                                    |            |
|----------------------------------------------------|------------|
| 6.1.1 Version 1 : The Linear-Lamp Resistance Model | 46         |
| 6.1.2 Version 2 : The Cubic Model                  | 46         |
| 6.2 Simulation Results of the proposed circuit     | 47         |
| <b>7. EXPERIMENTAL RESULTS</b>                     | <b>73</b>  |
| 7.1 Introduction                                   | 73         |
| 7.2 Electromagnetic Ballast                        | 73         |
| 7.3 Conventional Electronic Ballast                | 74         |
| 7.4 The Proposed Electronic Ballast                | 75         |
| 7.5 The Results with Modified Drive Circuit        | 78         |
| <b>8. CONCLUSION</b>                               | <b>103</b> |
| <b>REFERENCES</b>                                  | <b>104</b> |
| <b>APPENDICES</b>                                  | <b>106</b> |

## LIST OF TABLES

|           |                                                                                                      |            |
|-----------|------------------------------------------------------------------------------------------------------|------------|
| Table 2.1 | Fourier spectrum of supply current with parallel loaded electronic ballast                           | Page<br>15 |
| Table 6.1 | Simulation results at $d = 0.4$ $L_s = L_b$ Spectrum analysis of the supply current                  | 54         |
| Table 6.2 | Simulation results at $d = 0.4$ $L_s = L_a$ Spectrum analysis of the supply current                  | 55         |
| Table 6.3 | Simulation results at $d = 0.4$ $L_s = L_b$ Spectrum analysis of the supply current                  | 59         |
| Table 6.4 | Simulation results at $d = 0.2$ $L_s = L_b$ Spectrum analysis of the supply current                  | 63         |
| Table 6.5 | Simulation results at $d = 0.3$ $L_s = L_b$ Spectrum analysis of the supply current                  | 64         |
| Table 6.6 | Simulation results at $d = 0.5$ $L_s = L_b$ Spectrum analysis of the supply current                  | 65         |
| Table 7.1 | Spectrum analysis of the supply current using electromagnetic ballast                                | 79         |
| Table 7.2 | Fourier components of the supply current for conventional electronic ballast without series inductor | 82         |
| Table 7.3 | Fourier components of the supply current for conventional electronic ballast with series inductor    | 83         |
| Table 7.4 | Spectrum analysis of the supply current for the proposed electronic ballast at $d = 0.4$ $L_s = L_a$ | 86         |
| Table 7.5 | Spectrum analysis of the supply current for the proposed electronic ballast at $d = 0.4$ $L_s = L_b$ | 86         |
| Table 7.6 | Spectrum analysis of the supply current for the proposed electronic ballast at $d = 0.2$ $L_s = L_b$ | 89         |

|            |                                                                                                                                    |     |
|------------|------------------------------------------------------------------------------------------------------------------------------------|-----|
| Table 7.7  | Spectrum analysis of the supply current for the proposed electronic ballast at $d = 0.3$ $L_s = L_b$                               | 89  |
| Table 7.8  | Spectrum analysis of the supply current for the proposed electronic ballast at $d = 0.5$ $L_s = L_b$                               | 90  |
| Table 7.9  | Spectrum analysis of the supply current for the proposed electronic ballast at $d = 0.36$ $L_s = L_b$                              | 91  |
| Table 7.10 | Proposed electronic ballast with $L_s = L_b$                                                                                       | 96  |
| Table 7.11 | IEC standard for harmonic currents and corresponding values for the proposed circuit at $d = 0.4$                                  | 97  |
| Table 7.12 | European standard for harmonic currents and corresponding values for the proposed circuit at $d = 0.4$                             | 97  |
| Table 7.13 | Supply current and illumination intensity of the proposed circuit as a percentage of that at 50 Hz with modified drive circuit     | 100 |
| Table 7.14 | Harmonic components of the supply current for the proposed circuit as a percentage of that at 50 Hz with modified drive circuit    | 100 |
| Table 7.15 | Spectrum analysis of the supply current for the proposed electronic ballast (Simulation and experimental) at $d = 0.4$ $L_s = L_b$ | 102 |

# LIST OF FIGURES

|                                                                                       | Page |
|---------------------------------------------------------------------------------------|------|
| Figure 2.1 Supply voltage and current with electromagnetic ballast                    | 8    |
| Figure 2.2 Parallel Loaded Inverter Electronic Ballast                                | 9    |
| Figure 2.3 The voltage across the LC network with the load $V_{ab}$                   | 10   |
| Figure 2.4 Supply voltage and current with parallel loaded electronic ballast         | 14   |
| Figure 2.5 Switch voltage and current with parallel loaded electronic ballast         | 17   |
| Figure 3.1 Basic rectifiers with capacitor filter                                     | 20   |
| Figure 3.2 Series inductor filter                                                     | 21   |
| Figure 3.3 Parallel-connected resonant filter PCRF                                    | 21   |
| Figure 3.4 Series connected resonant filter SCRF                                      | 22   |
| Figure 3.5 Boost converter with power factor correction                               | 23   |
| Figure 4.1 Circuit configuration                                                      | 24   |
| Figure 4.2 Equivalent circuit during on period                                        | 25   |
| Figure 4.3 Equivalent circuit during off period                                       | 26   |
| Figure 4.4 Supply voltage                                                             | 26   |
| Figure 4.5a Steady state of supply current and voltage at $L_s = L_a$                 | 30   |
| Figure 4.5b Steady state of supply current and voltage at $L_s = L_b$                 | 31   |
| Figure 5.1 MOSFET equivalent circuit including terminal voltage dependent capacitance | 37   |
| Figure 5.2 Voltage drive for the power MOSFET                                         | 37   |