•Guidelines for Authors•

This periodical is a publication of the Academic Publishing and Translation Directorate of Qassim University. Its purpose is to provide an opportunity for scholars to publish their original research.

Manuscripts will be published in on of the following platforms:

i) **Article:** It should be original and has a significant contribution to the field in which the research was conducted.
ii) **Review Article:** A critical synthesis of the current literature in a particular field, or a synthesis of the literature in a particular field during an explicit period of time.
iii) **Brief Article (Technical Notes):** A short article (note) having the same characteristics as an article.
iv) **Innovation and Invention Reports**
v) **Forum:** Letters to the Editor, comments and responses, preliminary results or findings, and miscellany.
vi) **Book Reviews**

The Editorial Board will consider manuscripts in the following fields:

- Electrical Engineering
- Civil Engineering
- Mechanical Engineering
- Chemical Engineering
- Computer Engineering
- Mining and Petroleum Engineering
- Computer Science
- Information Technology
- Information Systems
- Basic Engineering and Computer Sciences

A manuscript should be submitted in English, and, if accepted for publication, it should not be published elsewhere without the written permission of the Editor-in-Chief.

General Instructions

1. **Submission of manuscripts for publication:** Papers must be presented in final page format (not more than 20 pages, A4 size), along with a compact disk (CD) containing the contribution executed on a PC using MS Word or any updated version of it. Manuscripts should be typed using Times New Roman, 12 points font, and one and half space. Pages are to be numbered consecutively and are to include all illustrative material, such as tables and figures, in their appropriate places in the text. If the author does not follow these guidelines, the paper is likely to be rejected or delayed.
2. **Abstracts:** Manuscripts for articles, review articles, and brief articles require both Arabic and English abstracts, using not more than 200 words..
3. **Keywords:** Each article must have keywords before both abstracts (English and Arabic) and they should not exceed 10 words.
4. **Tables and other illustrations:** Tables, figures, charts, graphs and plates should be planned to fit the Journal's page size (A4 incl. running heads). Line drawings are to be presented on high quality tracing paper using black India ink. Copies are not permitted for use as originals. Line quality is required to be uniform, distinct, and in proportion to the illustration. Photographs may be submitted on glossy print paper, in either black and white, or color, or made by using Adobe Photoshop. Tables and other illustrative material must include headings or titles, and captions for figures.

5. **Abbreviations:** The names of periodicals should be abbreviated in accordance with *The World List of Scientific Periodicals.* e.g., *et al., J. of Food Sci.*
For weights and measurements, and where appropriate, abbreviations rather than words are to be used, e.g., cm, mm, m, km, cc, ml, g, kg, min, %, etc., Fig.
Latin abbreviations such as: *op. cit., loc. cit., ibid.,* are to be in italic (if they are used).
6. **References:** References are mentioned numerically [between brackets] in the text and a list of references are provided at the end of the manuscript as follows:
a- Journals: [number] followed by the last name of the author (authors), First name or abbreviation, "paper title" , journal title , volume and issue numbers, (the year of publications between) , and page numbers.
Example: Sawyer, D. A. "Pounding of Rainwater on Flexible Roof Systems," Proceedings ASCE, Journal of the Structural Division, Vol. 93, No. 1, (1967), pp.127-147.
b- Books: Book references must include author, book title, the publisher's location, and publisher, and the year of publication.
Example: Feld, J., and Carper, K., Construction failure*,* 2^{nd} Ed., New York, Wiley, 1997.
7. **Content Note or Footnote:** A content note or footnote is a note from the author to the reader providing clarifying information.
A content note is indicated in the text by using a half-space superscript number (e.g. … books[3] are …). Content notes are to be sequentially numbered throughout the text. A reference may be cited in a content note by the use of the standard (Author, Date) style in the same way they are used in the text.
Content notes are to be presented below a solid half-line separating them from the text of the page in which the footnote is mentioned (in single column). Use the same half-space superscript number assigned in the content note(s) in the text to precede the content note itself.
8. **Proofs:** No changes, additions or deletions will be allowed in the pageproof stage.
9. **Opinions:** Manuscripts submitted to the Journal for publication contain the author's conclusions and opinions and, if published, do not constitute a conclusion or opinion of the Editorial Board.
10. **Offprints:** Two copies of the journal and twenty reprints of the accepted papers will be sent to the authors.
11. **Correspondence:** All correspondence may be addressed to:
Prof. Dr Mohamed A Abel-halim (Editor in Chief)
E-mail: quecjour@qec.edu.sa
12. **Frequency:** …Two issues per year…….
13. **Subscription and Exchange:**
Prof. Dr Mohamed A Abel-halim (Editor in Chief)
E-mail: quecjour@qec.edu.sa

In The Name of ALLAH,
Most Gracious, Most Merciful

Volume (1) No. (1)

Journal of Engineering and Computer Sciences

(January 2008) (Muharram 1429H)

(Qassim University Publications)

(Refereed Journal)

Qassim University

Academic Publishing & Translation

Buraydah - P. O. Box 6666 -51452

EDITORIAL BOARD

Deposif: 1429/2023

Forward I: Engineering, a Long Journey to Excellence

Scientific journals play a critical role in the advancement of engineering science by communicating knowledge from the researcher(s) to the larger scientific community. Recognizing its key responsibility towards students, academic staff, and the scientific and industrial communities as a whole, Qassim University took the initiative to launch its "Journal of Engineering and Computer Science, QUJECS". Among the objectives of QUJECS are: increasing the awareness of the importance of scientific research among the industrial community in Saudi Arabia and keeping up with the new developments and advances in engineering and computer sciences and practices.

During the celebration of the American National Academy of Engineering announcing their selected list of the 20 greatest engineering achievements of the twentieth century, former astronaut Neil Armstrong noted that, "Almost every part of our lives underwent profound changes during the past 100 years thanks to the effort of engineers, changes impossible to imagine a century ago. People living in the early 1900s would be amazed at the advancements wrought by engineers." He added, "As someone who has experienced firsthand one of engineering’s most incredible advancements-space exploration-I have no doubt that the next 100 years will be even more amazing."

In the century just ended, engineering recorded its grandest accomplishments. The widespread development and distribution of electricity, clean water, automobiles, airplanes, radio, television, spacecraft, lasers, antibiotics, medical imaging, computers and the Internet are just some of the highlights from a century in which engineering revolutionized and improved virtually every aspect of human life. Through these engineering accomplishments, the world has become smaller, more inclusive, and formidable as any from millennia past. As the population grows and its needs and desires expand, the problem of sustaining civilization’s continuing advancement, while still improving the quality of life, looms more immediate.

One might say that science does not truly exist until it is published, at which time the publication becomes a public commodity. The exchange of information through publication is an essential part of doing science, a public good, and, for some, a moral imperative. It is important that scientific societies, as major publishers of science, take initiatives to preserve the integrity of the process that certifies and communicates research. Therefore, at Qassim University, we have what it takes to seize the opportunities and rise to the challenges ahead. We start this journey with a small step; however, we will journey confidently towards achieving excellence in education and research. “Qassim University Journal of Engineering and Computer Sciences” is keen to play a key role in linking scientific research with practice.

Rector of Qassim University

Khalid A. Alhamoudi

Forward II: The Engineering Challenges of the 21st Century

We are pleased to launch the first issue of Qassim University Journal of Engineering and Computer Sciences (QUJECS). We hope that it will have a considerable impact on both the scientific and the industrial communities in Saudi Arabia and in the world at large.

The modern civilization is the product of both engineering and computer technologies. Thus, it is of paramount importance to consider what those technologies have rendered for humanity. In modern life, the Industrial Revolution has produced machines and engines which supplemented or replaced manpower. This has improved mining, engine ships, trains, factories, and the sanitation system, all of which have improved the human well-being in every respect of life.

Two engineering achievements are hoped for to have great impact on human life and are still waited for:

1. The first is Carbon 60, better known as Buckminsterfullerene, which is expected to provide a material that is lighter and stronger than metal. This will revolutionize every respect of life and make the access to Near-Earth space possible through the Space Elevator. Wires made of individual carbon items could reduce the size of today's microchips several times. Since carbon nanotubes (CNT) have been researched and used in initial experimental applications, nano-engineering has the task of developing production technologies to make CNT application commonplace. Research has shown that CNT is usable as a semiconductor for transistors: the basic elements for every computer. CNT could decrease the size of microchips many times. This is significant as the industry will need alternative technologies for further innovations. Nanotechnology is expected to produce hundreds of new innovations.
2. The other is the feasibility of Low Energy Nuclear Reaction, which is assumed to produce 10 times energy than its input, a claim recently made in England. If confirmed, our world will be changed beyond recognition. It would be the end of the Oil Age; then, we should be eating oil not burning it!!

Neither the engineering nor the computer achievements would have been influential so much in human life without the scientific journals. They have helped in communicating these achievements worldwide. Furthermore, scientific journals play a significant role in the improvement of academic institutions as they are the scientific window of research for staff, students, and industrial organizations.

We hope that this first issue of the Journal will have a positive reaction in the world of Academia at Qassim University and outside. We appreciate any comments and suggestions to raise the quality of the Journal to make it an international "Journal of Engineering and Computer Sciences".

Prof. Saleh A. Al-Damegh
Vice President of Graduate Studies and Research (Qassim University)

Engineering and Computer for a Better Future

Recently, there are many and various engineering and computer subjects which are studied, developed and tried to be applied in several life aspects. The fast development in the engineering and computer sciences and their associated technology play a very pronounced role in the welfare and the economical growth of the world. In the following sections, examples of these subjects will be illustrated:

- Whether in the form of electricity, heat, light, mechanical, energy will become an ever more expensive commodity. Therefore, there is a great need to manage this resource effectively. New products made from new advanced materials can have a large impact by providing better storage, consumption or transportation of energy. Alternative sources of energy such as solar cells, fuel cells and renewable primary products are currently being investigated. These alternatives have great potential to find real life applications within the future years. The degree of success and implementation of the energy generation technologies mentioned above depends on developments in engineering science, which will overcome the current limitations of performance, stability and costs. If solar cells are to provide an alternative to fossil fuels, significant research needs to be done in order to develop new routes of crystalline silicon production amorphous silicon hybrid materials.
- One of the most challenging tasks will be to adapt and transform the engineer industry's dependence on fossil fuels. There are three aspects that could be pursued. One is to reduce the dependence on oil as a raw material for chemicals by conversion to gas, coal or to biomass as a feedstock. This would require many technological adjustments to the production process, depending on the source being utilized. The second is related to this and is the utilization of bio-processes to generate bio-fuels from appropriate biomasses. The third set of technologies is that which enables the production of hydrogen in a clean form, including new catalysts.
- Various technologies could play a vital role in managing energy in the future, from making processes more efficient (catalysts, biomass conversion, plant management), to realizing new developments (membranes for fuel cells, bio-refineries). Associated with these is the appropriate development of scale-up production processes, control technologies and analytical techniques for the production of materials and for plant operation (control).
- The electronics industry is one of the fastest changing and innovative industries in the world. A large portion of these changes can be attributed to the discovery and controlled manufacture of multi-functional materials, such as silicon-based semi-conductors, polycarbonates for optical-data storage and liquid crystals for displays. Therefore, further developments in the electronic industries will rely on research activities in material science to provide new products and technologies.
- Efficient lighting in the form of light emitting diodes could replace the light bulbs based on tungsten wire and fluorescent tubes. Heat and light management can be further supported through smart functional window coatings or layers. Thermoelectric devices are solid-state systems that can convert heat into electricity.
- One of the most pressing issues facing the world is the sustainable supply of fresh drinking water. Through the development of new types of filtering processes and membrane technologies, the efficient and cost-effective transformation of seawater into potable water could be realized. The development of smart refrigerators, which are energy-efficient, able to monitor the quality of food kept inside them, and to issue a warning when the food begins to spoil, would be advantageous. An extra feature would be for the fridge to monitor the presence of a standard set of food items, and to order any of these when they run out.
- With the ever-increasing demands for personal mobility and a world shortage of fossil fuels, there is a great need to develop fossil fuel-free vehicles, eco-friendly alternative transport methods and new energy sources. The projected numbers of privately owned vehicles are expected to continue increasing, and therefore systems for effective traffic management are necessary. There is also the concurrent need to develop new catalytic converters to minimize the greenhouse gases produced by vehicles. To enhance the security of road users, new driver aids need to be developed, including instant diagnostic systems. Vehicles composed of new materials with improved recyclability and biodegradability will benefit the environment, as will the ability to renew used parts and incorporate them into new vehicles. Such technologies will lead to eco-efficient cars, planes and ships.

- The fuel consumption of cars will be reduced by substituting steel with lighter polymeric materials in automobile construction, and by increasing the efficiency of petrol and diesel engines through the use of fuel additives. Advanced and composite materials with lightweight construction will greatly enhance the efficiency and environmental sustainability of the energy systems. New polymer materials can increase the efficiency of existing methods for energy source production, e.g. adding polymer materials to oil wells to block water or to improve oil production.
- The day-to-day job of a civil engineer has changed much since the Romans built roads, harbors, and aqueducts across Europe. The job is still about serving the clients and helping them to realize their ideas, whether the project involves one square block or spans a continent. Some aspects of the profession, though, have changed dramatically. We have many new materials, such as steel and textile fabrics, that the Romans didn't have to reinforce the concrete they used 2,000 years ago. Most recently, technology including personal computers, design software, GPS devices, and GIS systems has brought the profession squarely into the digital age.
- During the next decade, technology will continue to drive some of the most significant changes in the practice and application of civil engineering. These transformations will be as diverse as meeting increased client expectations to decreasing the fear of liability. If engineers and engineering firms understand the changing landscape and are prepared to adapt to the digital decade, they will be in a position to increase both profits and client satisfaction
- The wireless revolution of cellular phones began just over 15 years ago. But during this short time the cellular phone has changed from a status symbol to a necessity. This was helped by the dramatic advances in digital switching, multiple access techniques and microelectronics which reduce the cost and processing time. A combination of satellite communication and cellular phones is also moving closer to reality to provide more sophisticated services than just a telephone call such as TV broadcasting and internet access.
- As a result of rapid technological progress, the different communication systems of collecting, transporting, storing and processing information are rapidly converging. The combination of handling audio, video and data over one computer communication network has led to many applications in business, industry and military. Organizations with hundred of offices spread over a wide geographical area routinely expect to hold a meeting, seeing and hearing each other and even writing on a shared virtual blackboard via videoconference. Videoconferencing which is a computer-assisted communication is a powerful tool for eliminating the cost and time previously devoted to travel. Airlines, bookstores and fashion vendors have discovered that many customers like the convenience of shopping from home. Consequently, many companies provide catalogues of their goods and services on-line and take orders on-line. Telelearning may radically affect education; universities may go international as well as national. Telemedicine is only now starting to catch on (e.g., remote patient monitoring) but may become much more important.
- Signal processing methods that enable reliable communications in the presence of acoustic channel distortion should focus on optimal exploitation of limited communication resources (bandwidth and energy). Research areas of interest include adaptive modulation/detection, efficient coding, array processing, and interference suppression in high-rate links and communication networks. Data compression methods that address sonar, seismic, and video signals are of interest. Maximal compression ratios, together with reliability and power consumption trade-offs must be addressed in the context of underwater sensing and imaging.
- The capabilities offered by computers, software applications, telecommunications, and business process redesign– the analysis and design of work flows and process with and between organizations- working together, these tools have the potential to create a new type of industrial engineering, changing the way the discipline is practiced and the skills necessary to practice it. Those aspiring to improve the way things are done must begin to apply the capabilities of information technology to redesign business process. Business process design and information technology are natural partners, yet industrial engineers have never fully exploited their relationships.
- A major change in design and manufacturing during the past 50 years has been the growth of computer simulation as a design tool. It has become possible to simulate with increasing accuracy more areas of product performance. Companies have realized that this is an increasingly effective tool for providing better products at a lower cost. The importance of CS is ever increasing. We're discovering ways to build just about everything out of small, simple mechanisms glued together with software, so no matter what you do, CS tends to be there. The scope of this new CS is amazing: We're at the center of the action in biology, nanotechnology, particle physics.

If society is ever going to slash medical costs, CS will play the key role. In fact CS can be considered as a sort of universal science.

Scientists, university staff, researchers, engineers and computer specialists in the different branches and computer specializations play the most effective role in carrying out the research and the implementation concerning all the previously mentioned subjects. The efforts done by them are numerous. Nevertheless, these efforts may be repeated and duplicated as they are performed in different places all over the world. Therefore, the integration of these efforts is very important. For each effort to be a continuation of previous efforts and to appear as a ring in a chain, the concerned people should know about each other. The scientific journals serve this purpose, and offer the chance of scientific communication. Recognizing this; Qassim University decided to launch its Journal of Engineering and Computer Sciences.

The main objectives of QUJECS are to encourage the research in the engineering and computer fields, and to publish the distinguished researchers' contributions spreading the knowledge in the scientific and industrial societies.

The journal scope is covering many fields such as; civil, electrical, mechanical, chemical, mining, petroleum, computer engineering and the basic engineering sciences. Also, the journal is concerned with the computer specializations which involve information technology, information systems and computer science.

The editorial board is grateful to the higher chiefs and executives of Qassim University, and also to the personnel in charge of both colleges of Engineering and Computer, for their appreciated continuous support and guidance to launch the journal.

Editor in Chief

Prof. Mohammed A. Abdel-halim

Contents

Page

Journal of Engineering and Computer Sciences, Qassim University Vol. 1, No. 1, PP 1-18, (January 2008/Muharram 1429H.)

AC Chopper Controlled Grid-Connected Induction Generator

M. A. Abdel-halim*, M. M. Abdel-aziz and H.G. Mostafa*****
**Elec. Engineering Dept., College of Engineering, Qassim University,*
Qassim, Saudi Arabia, masamie@qec.edu.sa
*** Elec. Power and Machines Dept., Faculty of Engineering,*
Cairo University, Giza, Egypt, mmabdelaziz@ieee.org
****Electrical Eng. Dept., Faculty of Engineering, Modern Academy,*
Cairo, Egypt, haythamgamal8@yahoo.com

(Received 18/5/2007; accepted for publication 10/8/2007)

Abstract. Induction generators when driven by wind turbines are liable to run at different speeds, and they may run at a speed very near to its synchronous speed. At such low speed both the generator power factor and efficiency are bad. This paper presents complete analysis of an induction generator linked to the network through AC chopper aiming at exploring the extent of the enhancement of generator performance achieved by using AC choppers. The generator performance characteristics regarding the harmonic contents, active power, reactive power, power factor, torque ripples and efficiency have been computed at different speeds. These characteristics have been determined with the help of a novel abc-dq circuit model. The model possesses the advantages of both the dq and direct phase models. The performance characteristics have been compared with other control strategies to highlight the advantages and disadvantages of using the AC chopper as an interface between the network and the induction generator.

Keywords: Induction generator, AC chopper, Electronic control of induction generator, Wind driven induction generator, Control of generators.

List of Symbols

i	: Instantaneous current, p.u.
I_1	: R.M.S. value of the fundamental current.
I_n	: R.M.S. value of the harmonic current of order "n".
f, f_{ch}	: Bus- and chopping- frequency, respectively.
P	: Normalized operator (d/ωt)
R_s, R_r	: Stator and rotor resistances, respectively, p.u.
t_{off}, t_{on}	: Chopper off and on periods, respectively.
T_{ch}	: Chopper period.
T	: Torque, p.u.
v	: Instantaneous voltage, p.u.
X_M, X_{sl} , X_{rl}	: Magnetizing, stator leakage and rotor leakage reactances, p.u.
τ	: Time ratio $[t_{on}/(t_{on}+t_{off})]$.
ω, ω_m	: Angular frequency and mechanical speed, rad/sec.

Subscripts

a, b, c	: Stator phases
d, q	: Rotor d- and rotor q- axis, respectively

1. Introduction

The wind energy is progressively used nowadays to generate electric power in either a grid or an autonomous system depending on the location and the potentials of the available wind energy source [1]. The active and reactive powers of the grid-Connected induction generator are completely determined by its speed and terminal voltage. The power factor is fixed by its slip and its equivalent circuit parameters and not affected by the voltage. The grid-Connected induction generator, when driven by wind turbines, is liable to run at different speeds. The generator output active and reactive power can be controlled through the variation of its terminal voltage.

In this respect, Abdel-halim [2] proposed a control method for induction generator linked to the network through transistorized AC voltage controller employing forced commutation technique. Firing angle, extinction angle and symmetrical angle control strategies have been applied. Abdel-halim, Alolah and Almarshoud [3] proposed other control method for induction generator linked to the network through AC voltage controller utilizing anti-parallel naturally-commutated thyristors. The extinction angle and the symmetrical angle control strategies increase the current displacement angle. Also, the natural commutation control strategy increases this angle. On the other hand, the firing angle control technique improves the displacement angle over most of the control range. All the previous methods result in quite large voltage harmonic contents of low orders such as the third and fifth multiples of the power frequency. This results in generator bad efficiency, low power factor and certainly high electromagnetic torque ripples. Also, the network injected harmonic currents being of low orders are difficult to be filtered.

To avoid most of the previously mentioned disadvantages, the present paper suggests using an AC chopper as an interface between the stator terminals of induction generator and the network [4]. The use of AC chopper is promising as it results in only high order harmonic contents of low levels. To study this system, the induction generator is modeled using a developed abc-dq circuit model. The performance characteristics are obtained through a comprehensive mathematical model. The model is able to account for the discontinuities introduced by the switching actions of the AC voltage controller. Also, it is capable of dealing with different switching strategies.

The performance characteristics of the generator employing the AC chopper will be compared with those resulting when using other control strategies to evaluate the use of the AC chopper.

2. Proposed Control Circuit

The schematic diagram of the proposed system is shown in Fig. 1. Each stator phase has control circuit that consists of two transistor AC switches, one Connected in series and the other Connected in parallel. Each AC switch is a pair of inverse parallel Connected power transistors. A diode is Connected in series with each to block reverse voltage. The output voltage will be smoothly controlled from zero to full bus voltage by varying the time ratio of the chopping transistors. The series transistors act as chopping switches. The shunt transistor provides a freewheeling path when the series one is turned off.

3. System Modeling

The induction machine is modeled using Abdel-halim model [2]. Rather than the dq model [5] The stator is modeled in the direct phase reference frame (abc), while the rotor is modeled as two pseudo-stationary coils in the dq reference frame (Fig. 2). This new model has the advantages of both the dq and direct phase modelling.

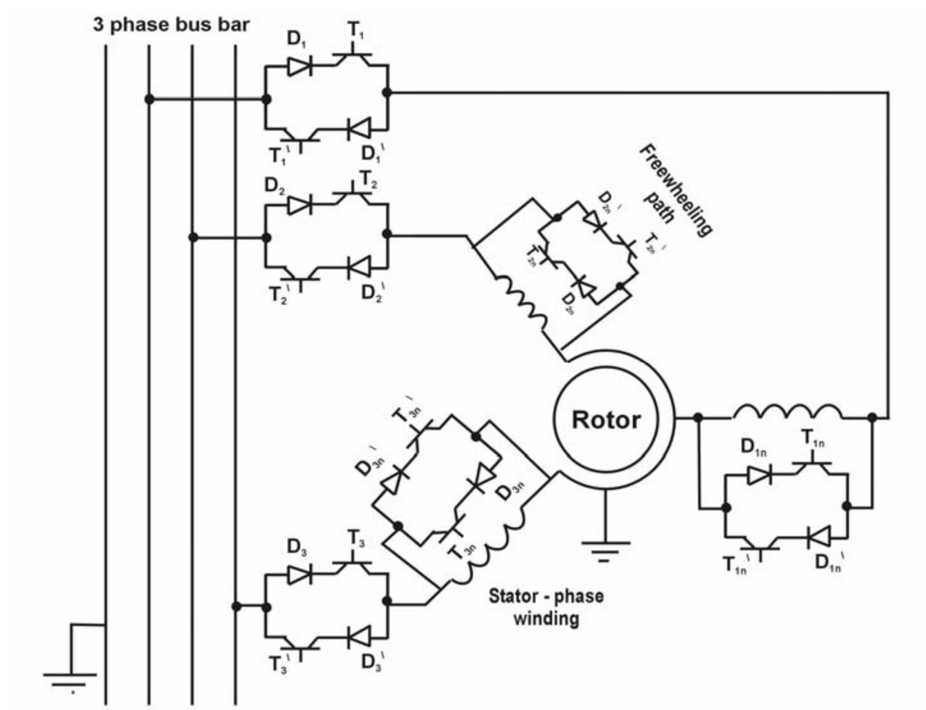

Fig. (1). Induction generator Connected to grid via AC chopper.

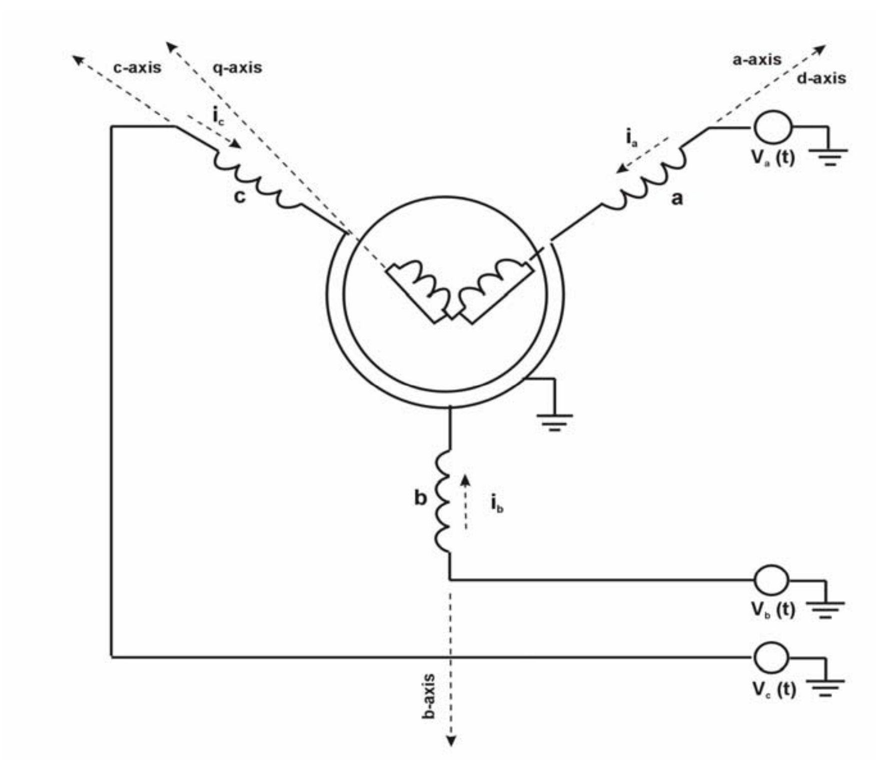

Fig. (2). Circuit model of induction machine.

The five coil currents and the rotor speed are chosen to be the state space variables. Based on the previous circuit model and neglecting the iron losses and saturation effects, the voltage matrix equation of the machine is formulated in p.u. as follows:

$$[V] = [R]\,[i] + [X]p[i] + \omega_m\,[G]\,[i] \tag{1}$$

where [R] [i] is the resistive voltage drop, [X]p[i] is the transformer voltage, and ω_m [G] [i] is the rotational voltage. The resistance matrix is given by [2]:

$$[R]=\begin{bmatrix} R_s & 0 & 0 & 0 & 0 \\ 0 & R_s & 0 & 0 & 0 \\ 0 & 0 & R_s & 0 & 0 \\ 0 & 0 & 0 & \frac{2}{3}R_r & 0 \\ 0 & 0 & 0 & 0 & \frac{2}{3}R_r \end{bmatrix}$$

The reactance matrix is given by [2]:

$$[X]=\begin{bmatrix} \left(\frac{2}{3}X_M+X_{sl}\right) & \frac{-X_M}{3} & \frac{-X_M}{3} & \frac{2}{3}X_M & 0 \\ \frac{-X_M}{3} & \left(\frac{2}{3}X_M+X_{sl}\right) & \frac{-X_M}{3} & \frac{-X_M}{3} & -\sqrt{3}\frac{X_M}{3} \\ \frac{-X_M}{3} & \frac{-X_M}{3} & \left(\frac{2}{3}X_M+X_{sl}\right) & \frac{-X_M}{3} & \sqrt{3}\frac{X_M}{3} \\ \frac{2}{3}X_M & \frac{-X_M}{3} & \frac{-X_M}{3} & \frac{2}{3}\left(X_M+X_{rl}\right) & 0 \\ 0 & -\sqrt{3}\frac{X_M}{3} & \sqrt{3}\frac{X_M}{3} & 0 & \frac{2}{3}\left(X_M+X_{rl}\right) \end{bmatrix}$$

The rotational voltage coefficient matrix is given by [2]:

$$[G]=\begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & \sqrt{3}\frac{X_M}{3} & -\sqrt{3}\frac{X_M}{3} & 0 & -\frac{2}{3}(X_M+X_{rl}) \\ \frac{2}{3}X_M & \frac{-X_M}{3} & \frac{-X_M}{3} & \frac{2}{3}(X_M+X_{rl}) & 0 \end{bmatrix}$$

The transformer and the rotational voltage coefficient matrices have been formulated when the rotor d-axis is chosen along the magnetic axis of the stator phase (a). The voltage vector is:

$$[V] = [v_a, v_b, v_{c,}\ 0, 0]^T$$

where:

$v_a = \sin(\omega t)$ $\quad (t_{off} + nT_{ch}) \le t \le (t_{on} + nT_{ch})$

$= 0$ $\quad$ elsewhere

$n = 0, 1, 2, \ldots\ldots\ldots\ldots, f_{ch}/f.$

v_b and v_c are similar to v_a but shifted from it by 120° and 240° respectively.

The current vector is:

$$[i] = [i_a, i_b, i_{c,}\ i_{d,}\ i_q]^T$$

The bus current equals the generator current during the series-transistor on-period, otherwise it is zero. The per-unit electromagnetic torque measured in the direction of rotation of the machine is derived from the rotational power input to the machine [2] as:

$$T_e = \frac{2}{3}\left[\frac{\sqrt{3}}{3}(i_b - i_c)\, X_M\, i_d + \frac{(2i_a - i_b - i_c)}{3} X_M\, i_q\right] \qquad (2)$$

4. Performance Indices

The performance of the induction generator is judged by investigating the values and pattern of variation of some of the performance parameters; namely the fundamental current component, the total harmonic distortion, the distortion factors, the displacement angle, the power factor, the active and reactive powers, the torque ripples and the generator efficiency. The fundamental current component is calculated applying Fourier transformation [6]. The total harmonic distortion (THD) is calculated as follows [7]:

$$THD = \frac{\sqrt{I_{r.m.s}^{\,2} - I_1^{\,2}}}{I_1}$$

The distortion factor (D.F) and the individual harmonic component distortion factor ($D.F_n$) are calculated as follows [7]:

$$D.F = \frac{1}{I_1}\left[\sum_2^n \left(\frac{I_n}{n^2}\right)^2\right]^{1/2}$$

$$D.F_n = \frac{I_n}{I_1 . n^2}$$

The displacement angle (ϕ_{b1}) is defined as the phase shift between the fundamental current component of the bus bar and the bus voltage when the current sense is taken in the outward direction of the machine.

The generator power factor at the bus-bar is calculated as follows [7]:

$$P.F = \frac{I_{b1}}{I_b} \cos \phi_{b1}$$

The per-unit active and the reactive powers associated with the fundamental current component are calculated as follows:

$P = V_b I_{b1} \cos\phi_{b1}$

$Q = V_b I_{b1} \sin\phi_{b1}$

where V_b is the bus r.m.s voltage, I_{b1} is the r.m.s of the fundamental current component of the bus-bar, and Φ_{b1} is the displacement angle.

When using the AC chopper as a controller, in addition to the fundamental current component there will be harmonic components of frequency given by integer multiples of the chopping frequency ± the fundamental bus frequency [8]. Due to the harmonic currents, the electromagnetic torque will have unidirectional and pulsating components [8-10]. The unidirectional components are divided into the followings:

(i) A component produced by the synchronous rotating magnetic flux produced by the fundamental frequency current component.

(ii) Components produced by the forward rotating magnetic fluxes which are produced by the positive sequence harmonic current components.

(iii) Components produced by the backward rotating magnetic fluxes which are established by the negative sequence harmonic current components.

The pulsating torque components are produced due to the interactions between stator and rotor flux components having different speeds in the air gap. The frequency of any pulsating torque component depends on the relative speed between the two fluxes causing it.

The different torque components may be calculated by applying Fourier series to the torque points calculated using Eq. (2). The total torque ripples is defined approximately as half the peak to peak value of the electromagnetic pulsating torque developed by the induction generator. It can be expressed as follows:

$$T_{ripple} = \frac{T_{\max} - T_{\min}}{2}$$

The generator power efficiency is calculated as follows, neglecting the mechanical losses:

$$\eta = \frac{P}{P_{input}} \times 100 \quad \%$$

$$P_{input} = T_{AVG} \times \omega_m$$

5. Results and Discussion

A computer program has been developed to simulate the proposed induction generator system. Numerical integration using fourth order Runge-Kutta algorithm has been applied to compute the currents step by step in the time domain. For accurate detection of high order harmonic contents, a small time step has been used to ensure that at least two steps lie within the period of the highest studied harmonic order. Once the current waveform has been obtained, standard numerical techniques employing Fourier transformation and trapezoidal integration rule [6] have been applied to calculate the bus and stator phase (r.m.s) currents, harmonic factors, power factor, active and reactive power, torque components and the generator efficiency.

A three-phase induction generator having the specification and parameters given in Table 1 has been used for computations. The performance characteristics have been computed at different speeds for various time ratios (duty cycles) at a chopping frequency of 10000 Hz.

Fig. (3) shows the variation of the fundamental component of the generator current against the time ratio (τ). The current increases as the time ratio increases, and also increases if the generator is driven at higher speed. The fundamental component of the bus current generally behaves in a manner similar to that of the fundamental component of the generator current (Fig. 4).

The total harmonic distortion of the generator current increases as the time ratio decreases, and it decreases when the rotor speed increases (Fig. 5). The total harmonic distortion of the bus current increases as the time ratio decreases. The rotor speed nearly has no effect on the total harmonic distortion factor of the bus current (Fig. 6). The total harmonic distortion of the bus current is quite large, but these harmonic currents are of high frequency. Therefore, they may be easily filtered. This is clearly indicated by calculating the distortion factor. For the chosen chopping frequency (1000 Hz) the even harmonic orders do not exist, and the odd harmonics exist at frequencies which deviates from the multiples of the chopping frequency by the ac supply power frequency. As shown in Fig. 7, the distortion factor of the generator current increases as the time ratio decreases, and it decreases when the rotor speed increases. The distortion factors of the harmonic current contents of order "201" and "601" of the generator current behaves in a manner similar to that of the distortion factor of the generator current (Figs. 8 and 9). As shown in Fig. 10, the distortion factor of the bus current increases as the time ratio decreases. The distortion factors of the harmonic current contents of order "201" and "601" of the bus current behaves in a manner similar to that of the distortion factor of the bus current (Figs. 11 and 12). As shown in Figs. 13 and 14, the active and reactive powers are controlled by variation of the time ratio.

The displacement angle decreases slightly as the time ratio increases. It can be stated that it is almost constant at a certain speed. The displacement angle decreases as the rotor speed increases up to 1.02 p.u, then the displacement angle increases as the rotor speed increases further (Fig. 15). As shown in Fig. 16, the power factor of the machine under study starts at high value then decreases as the time ratio deceases until the power factor becomes zero when the time ratio equals zero. The speed nearly has no effect on the power factor.

The average electromagnetic torque of the machine under study behaves in a manner similar to that of the generator fundamental current as shown in (Fig. 17).

For a chopping frequency of 200 times the power frequency (10000 Hz), there will be harmonic current components of orders 199, 201, 399, 401, 599, 601, etc. The first significant pulsating torque components are produced due to the following interactions:

(i) A pulsating torque component at a frequency of 198f is produced by the interaction between the fundamental flux component and the 199^{th} harmonic flux component, and between the 401^{st} harmonic flux component and the 599^{th} harmonic flux component.

(ii) A pulsating torque component at a frequency of 402f is produced by the interaction between the fundamental flux component and the 401^{st} flux component, and between the 199^{th} flux component and the 601^{st} flux component.

(iii) A pulsating torque component at a frequency of 600f is produced by the interaction between the fundamental flux component and the 599^{th} harmonic flux component, and between the fundamental flux component and the 601^{st} harmonic flux component, and between the 199^{th} harmonic flux component and the 401^{st} harmonic flux component.

The total torque ripples is shown in Fig. 18. The pulsating torque component of order 600 is shown as an example in Fig. 19.

The efficiency of the machine under study decreases slightly by decreasing the time ratio, and it decreases if the rotor speed increases (Fig. 20).

Table (1). Parameters of the induction generator.

Rated voltage	**380 V**	**Rated current**	**40 A**
Frequency	50 HZ	R_s	0.012 p.u
X_{sl}	0.02 p.u	X_M	10.2 p.u
R_r	0.012 p.u	X_{rl}	0.0195 p.u

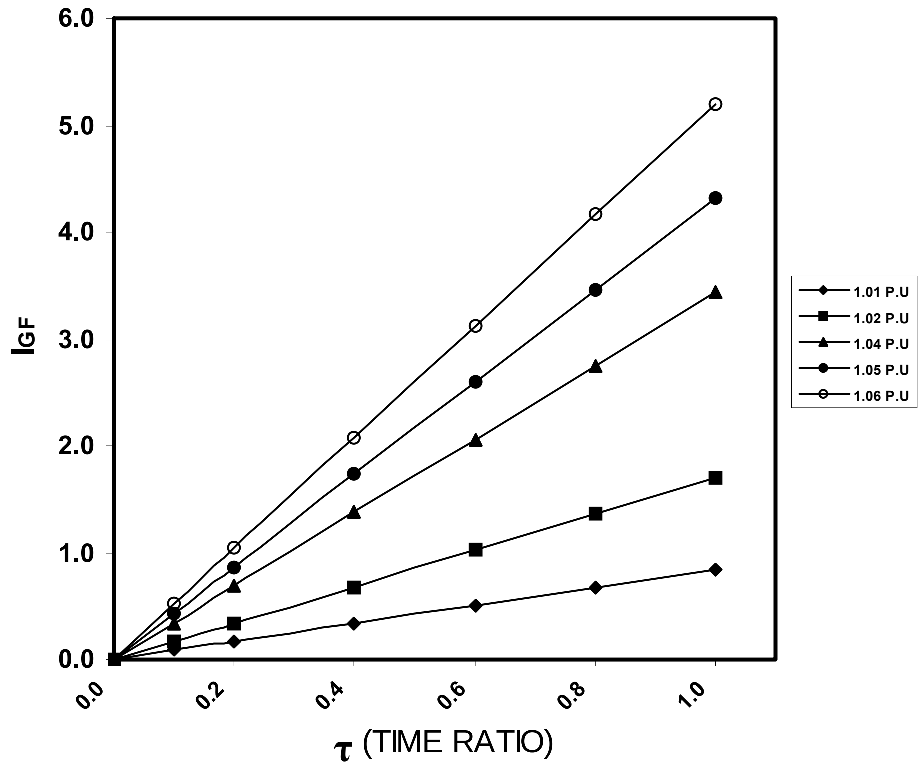

Fig. (3). Variation of the fundamental component of the generator current.

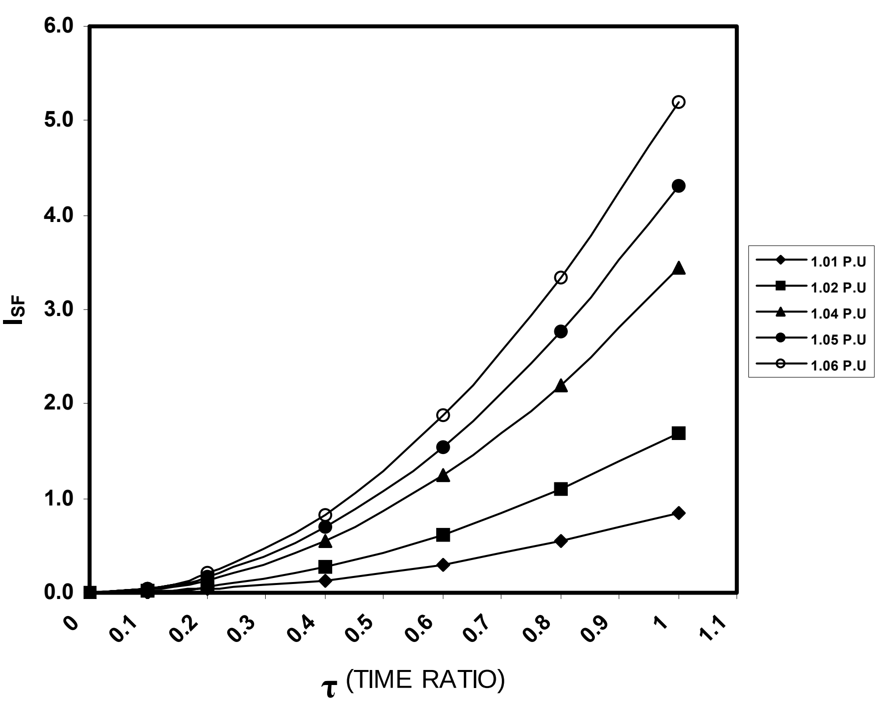

Fig. (4). Variation of the fundamental component of the bus current.

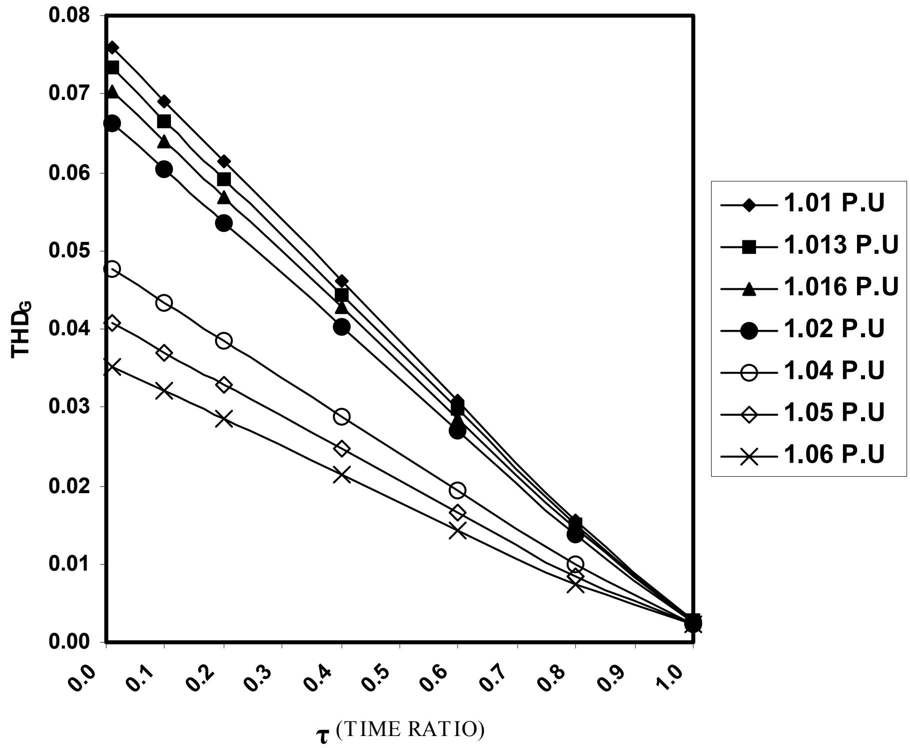

Fig. (5). Variation of the generator current total harmonic distortion.

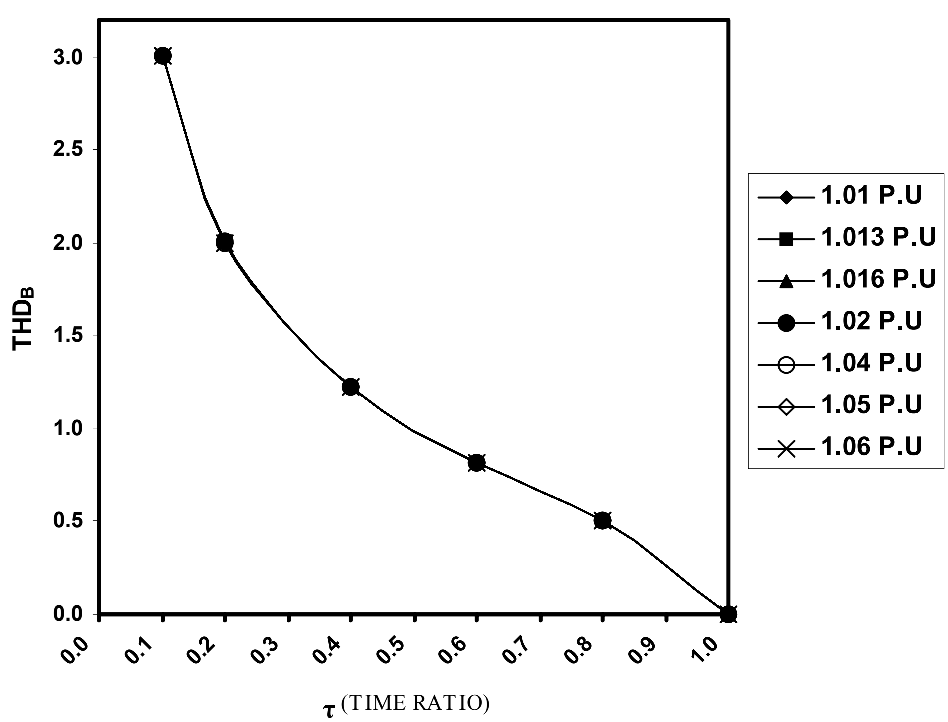

Fig. (6). Variation of the bus current total harmonic distortion.

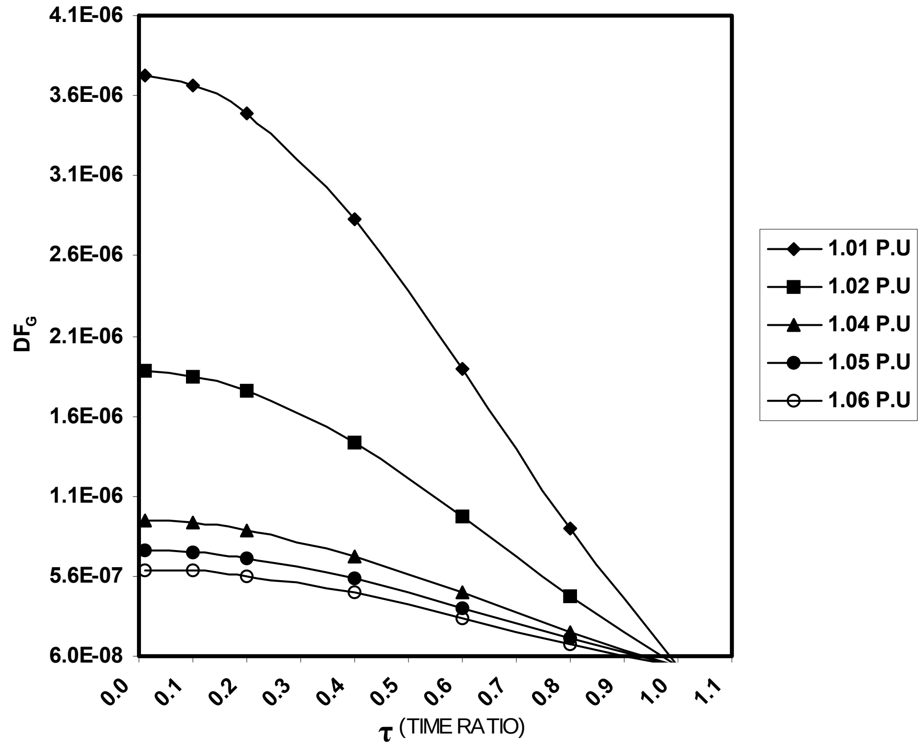

Fig. (7). Variation of the generator current distortion factor.

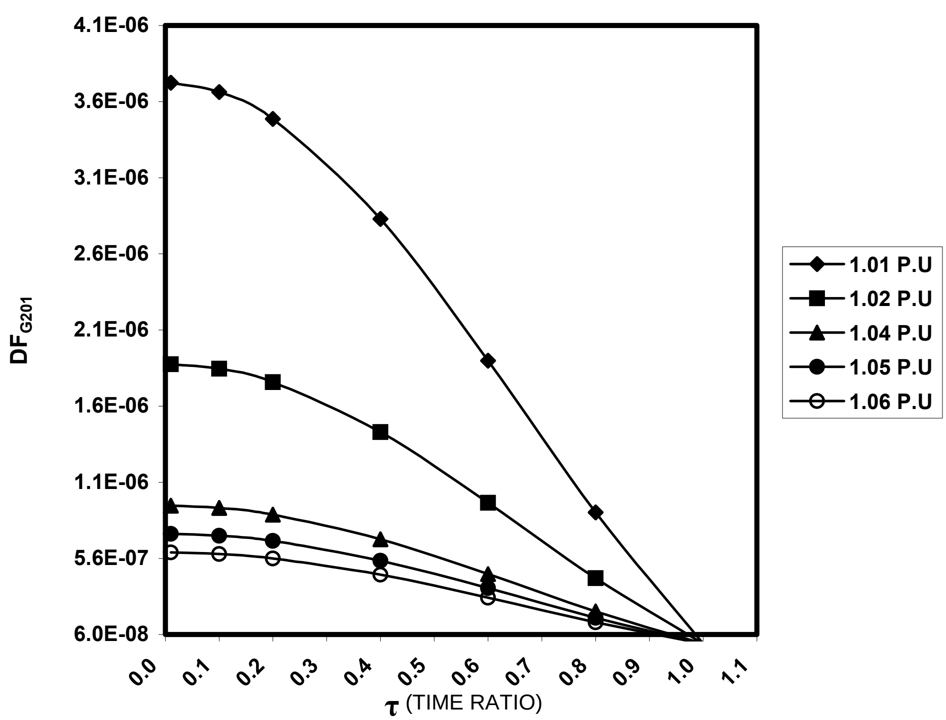

Fig. (8). The distortion factor of the generator 201st current component.

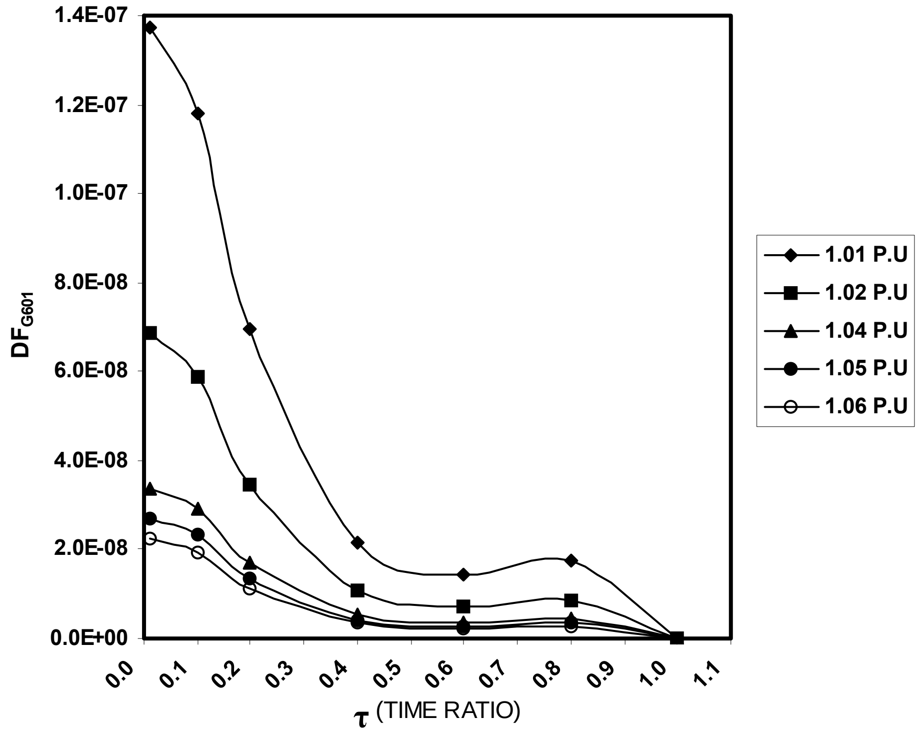

Fig. (9). The distortion factor of the generator 601st current component.

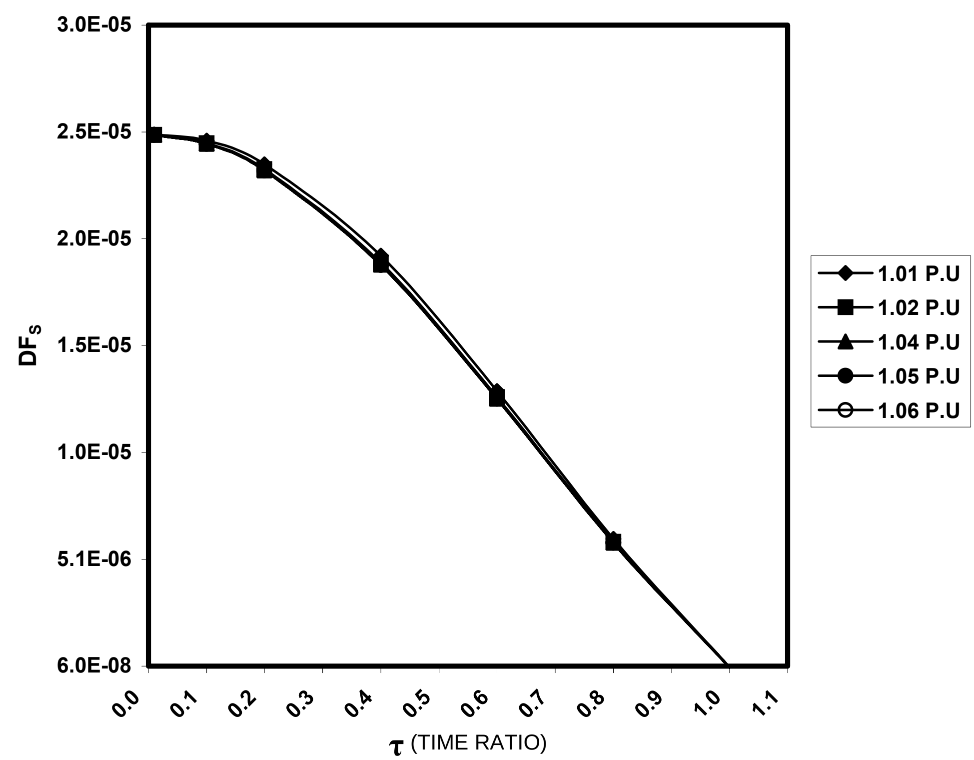

Fig. (10). Variation of the bus current distortion factor.

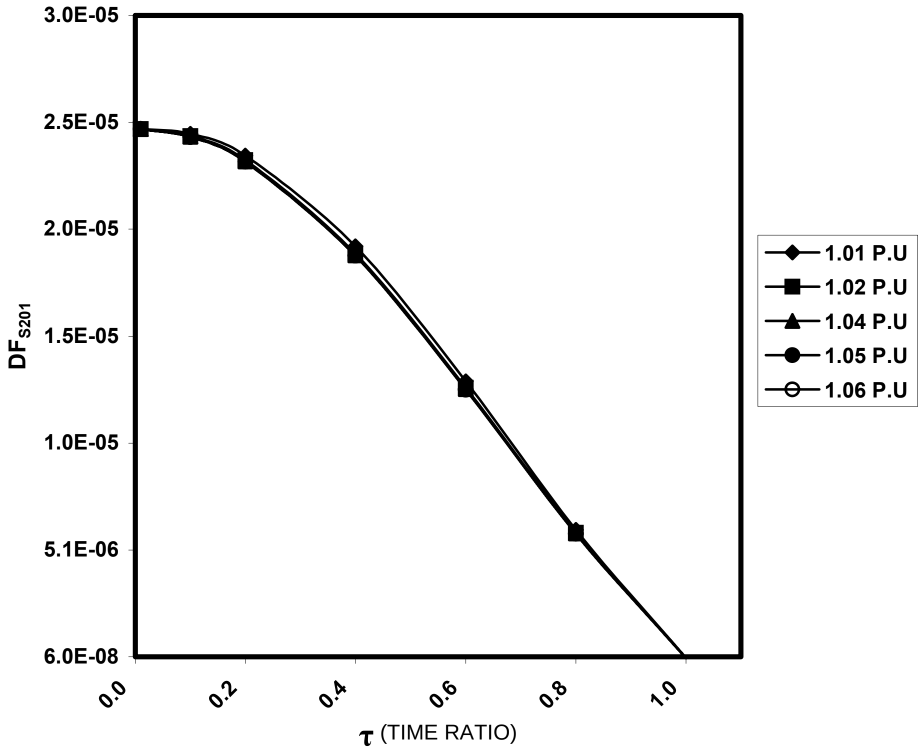

Fig. (11). The distortion factor of the bus 201st current component.

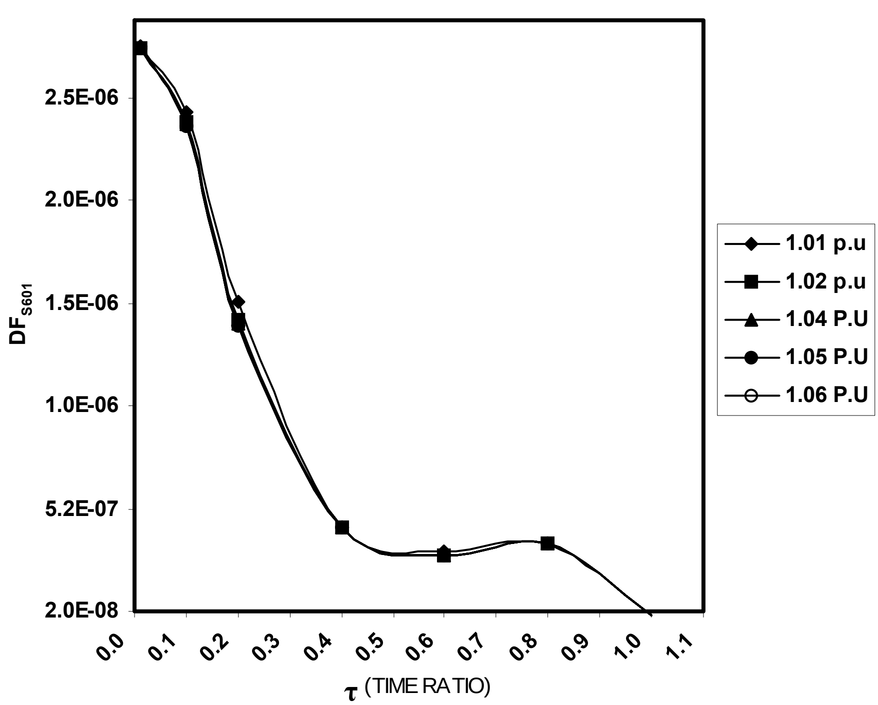

Fig. (12). The distortion factor of the bus 601st current component.

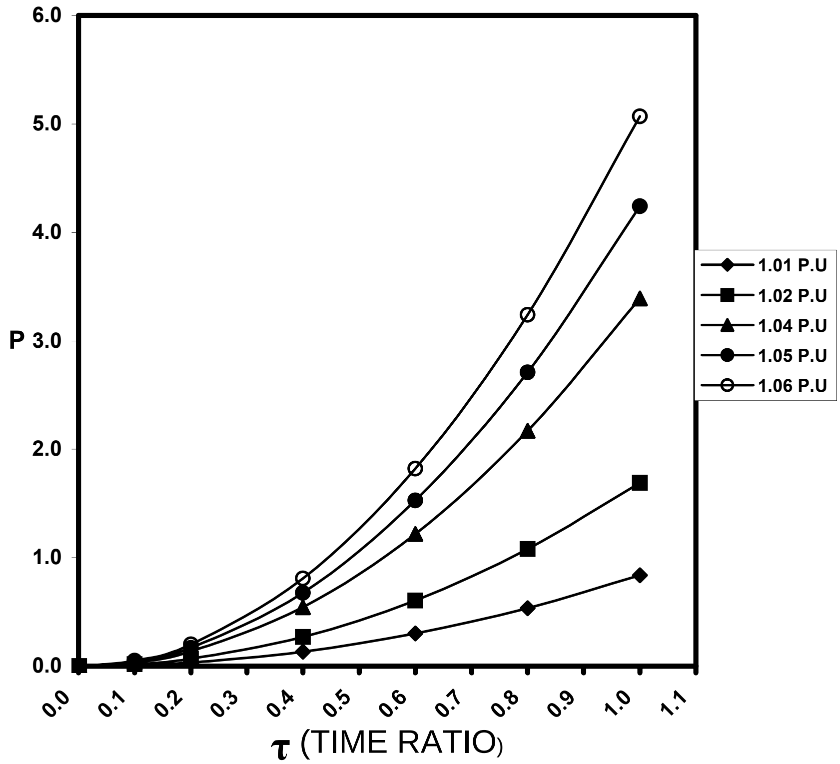

Fig. (13). Variation of the active power.

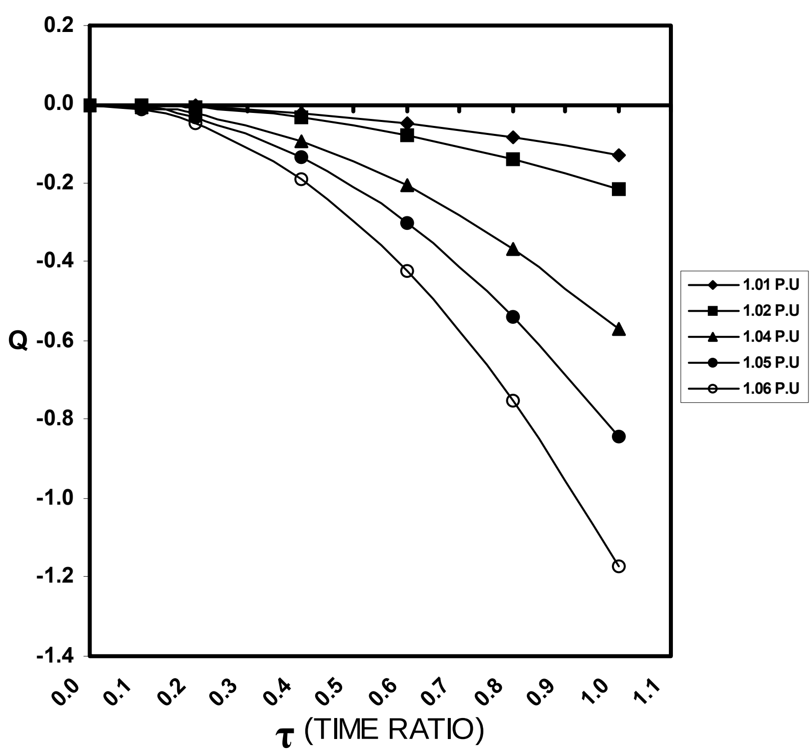

Fig. (14). Variation of the ractive power.

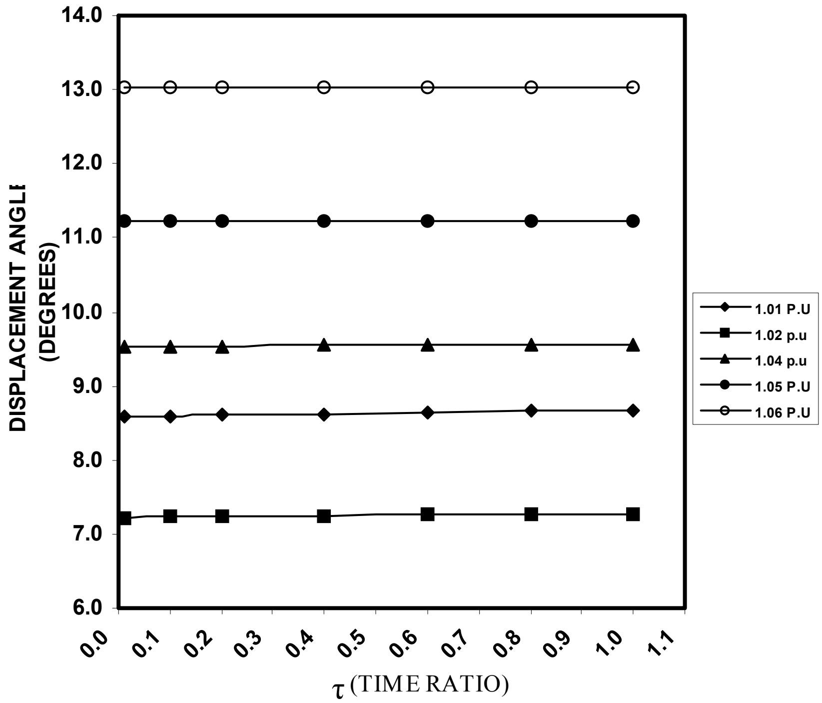

Fig. (15). Variation of the displacement angle.

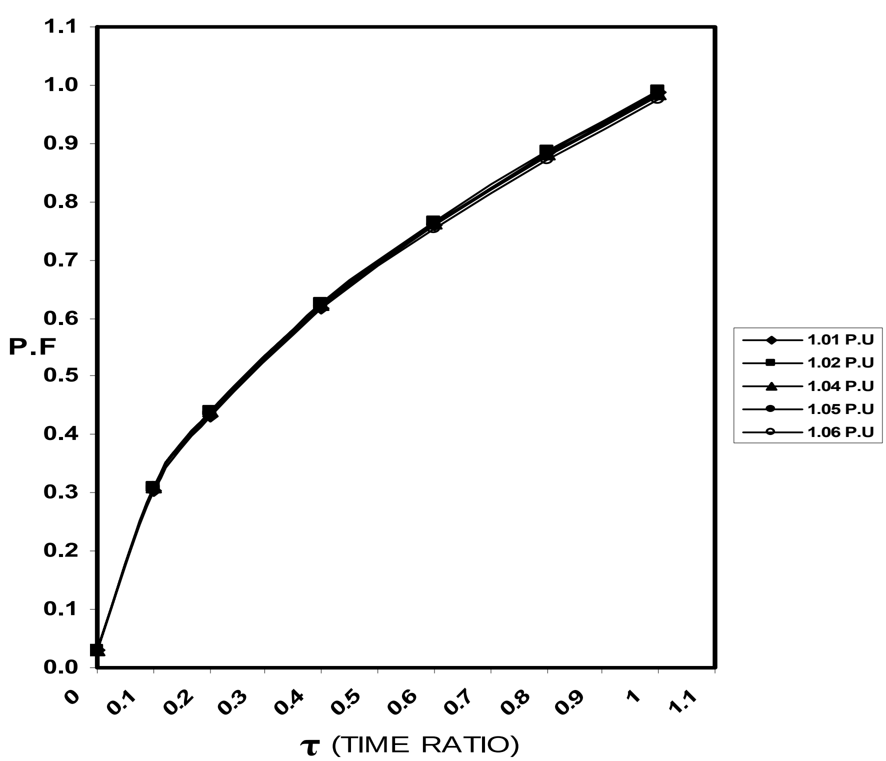

Fig. (16). Variation of the power factor.

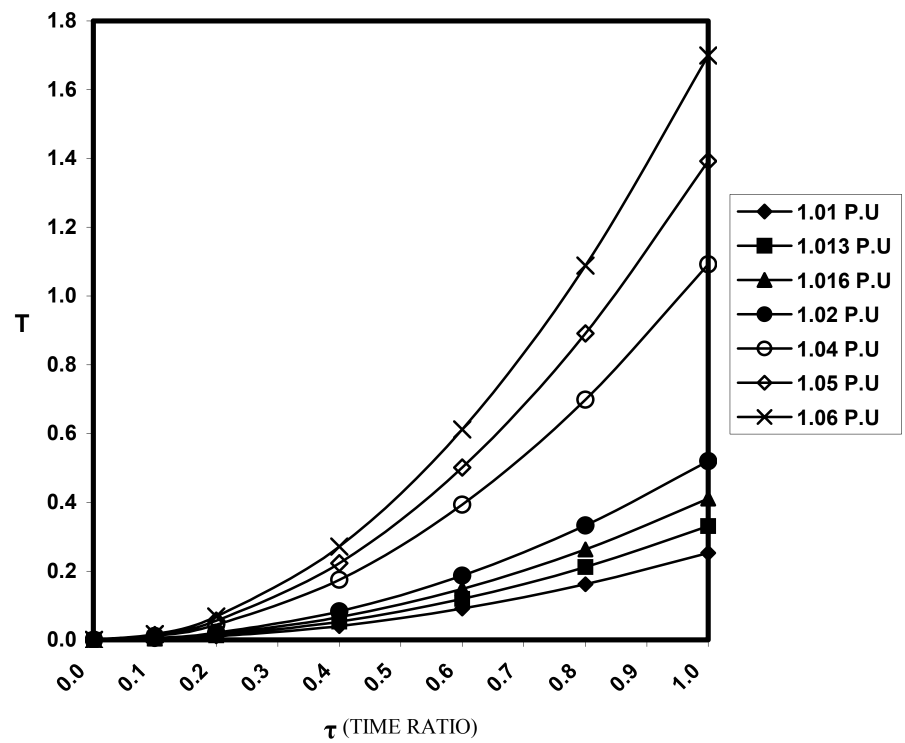

Fig. (17). The average electromagnetic torque.

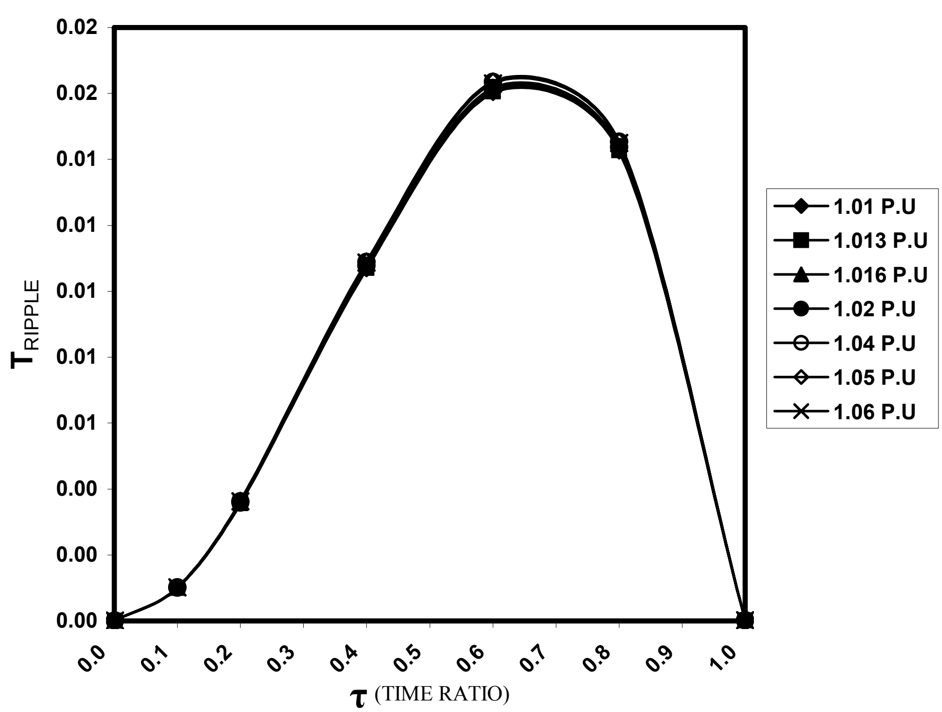

Fig. (18). The total torque ripples.

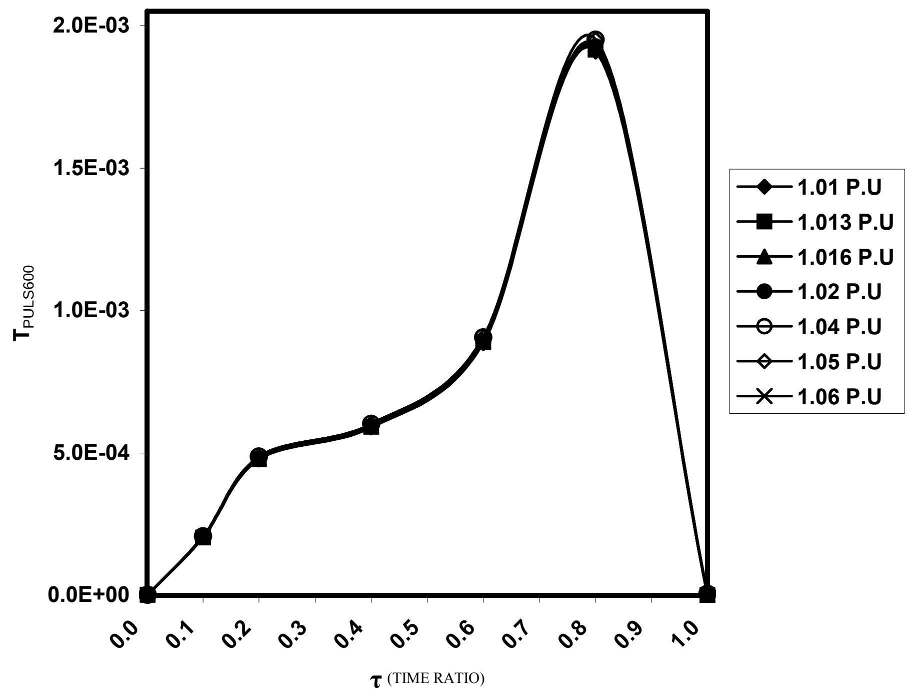

Fig. (19). The pulsating torque component of order 600.

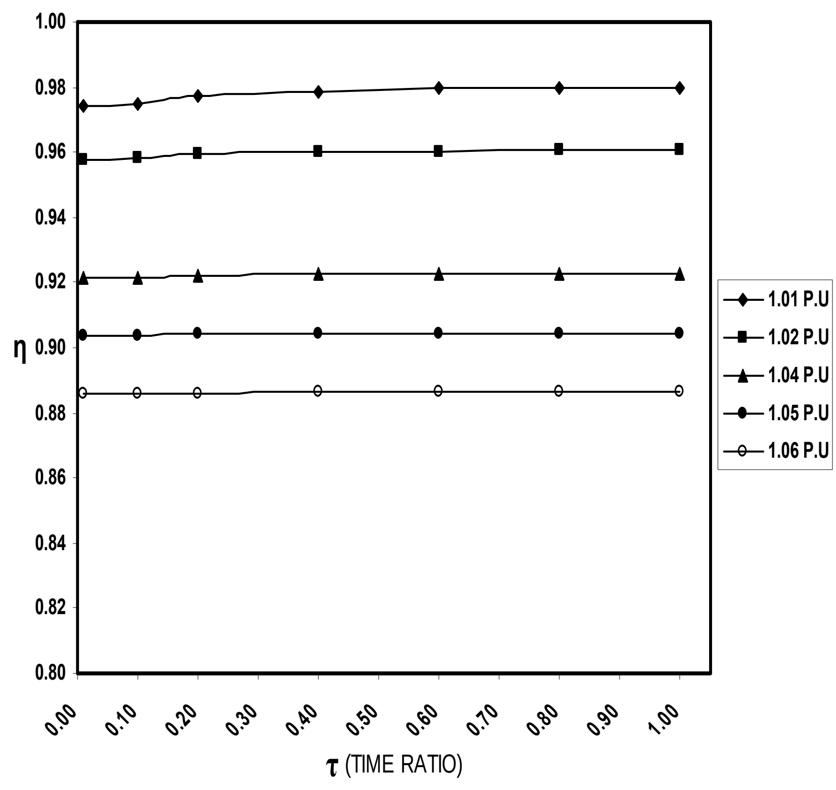

Fig. (20). The generator power efficiency.

6. Conclusions

The performance of grid-Connected induction generator has been studied using a solid state AC chopper as an interface between the grid and the stator terminals of the generator. The performance characteristics have been obtained through modeling the induction generator and the static converter by a novel equivalent circuit in a pseudo-stationary abc-dq reference frame.

When comparing the generator performance using AC chopper control strategy with the performance when using AC voltage controller employing natural and forced commutation control strategies published in previous papers [2, 3], the followings are concluded:

1. The AC chopper gives the least generator current distortion factor, while the forced commutation voltage controller results in the highest distortion factor.
2. The AC chopper gives the least bus-current distortion factor, while the forced commutation AC voltage controller using the extinction control strategy results in the highest distortion factor of the bus current.
3. The AC chopper control strategy also gives a nearly constant displacement angle compared to other control strategies.
4. The efficiency using AC chopping strategy is nearly constant for constant speed due to the constant proportionality of the active power and the input power keeping in mind that current harmonic contents resulted are too small.
5. The AC chopper control strategy gives very little pulsating toque components. These components have very high frequencies, and they are more probable to be far from the mechanical natural frequencies of the system. Thus, torsional oscillation problems are not encountered.
6. The AC chopper controller—when used to control the active and reactive powers of the induction generator—gives in general the best generator performance characteristics. The AC voltage controller employing firing angle control technique has one advantageous point compared with the others. It improves the displacement angle over a noticable control range compared with the constant value resulted from the AC chopper and the increasing value resulted from other controllers.

7. References

[1] Singh, B. “Induction Generators: A Prospective.” *Electric Machines and Power Systems Journal,* 23 (1993), 163-177.

[2] Abdel-halim, M.A. “Solid State Control of a Grid Connected Induction Generator.” *Electric Power Components and Systems Journal,* 29 (2001), 163-178.

[3] Almarshoud, A.F.; Abdel-halim, M.A. and Alolah, A.l. “Performance of Grid Connected Induction Generator under Naturally Commutated AC Voltage Controller.” *Electric Power Components and Systems Journal,* 32 (2004), 691-700.

[4] Babu, S.S.; Mariappan, G.J. and Palanichamy, S. “A Novel Grid Interface for Wind-driven Grid-Connected Induction Generators.” *Proceedings of the IEEE/IAS International Conference on Industrial Automation and Control,* 1995, 373-376.

[5] Adkins, B. and Harley, R.G. *The General Theory of Alternating Current Machines: Application to Practical Problems.* 1st ed., London: Chapman and Hall, 1975.

[6] Ralaston, A. *A First Course in Numerical Analysis.* New York, USA: McGraw-Hill, 1995.

[7] Rashid, M. H. *Power Electronics: Circuits, Devices, and Applications.* 4th ed., USA: Prentice Hall, 2002.

[8] Mostafa, H.G. “Modelling and Analysis of a Grid Connected Induction Generator Using A.C Voltage Controller.” *M.Sc. Thesis, Faculty of Engineering,* Cairo University, Egypt, 2006.

[9] IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems, *IEEE Std. 519-1992,* IEEE, New York, 1993.

[10] Abdulrahman, S.M.; Borough, J.G.K. and Smith, I.R. “Fast Calculation of Harmonic Torque Pulsations in a VSI/Induction Motor Drive.” *IEEE Trans. on Industrial Electronics,* 40, No. 6 (December 1993), 561-569.

مولد حثي مربوط بالشبكة و كوم قطع التيار ا تردد

مد عبد السميع عبد ا ليم*، مد دوح عبد العزيز، هيثم ال مصطفى*****

**قسم ا ندسة الكهربائي، كلية ا ندسة - جامعة القصيم، القصيم، ا ملكة العربية السعودية*

***قسم ا ندسة الكهربية، كلية ا ندسة - جامعة القاهرة، ا يزة - مصر*

****قسم ا ندسة الكهربية، الأكاد ية ا ديثة، القاهرة - مصر*

(قُدم للنشر في ١٨/٥/٢٠٠٧م ؛ وقُبل للنشر في ١٠/٨/٢٠٠٧م)

ملخص البحث. نتيجة للتوسع في استغلال طاقة الرياح كثر حديثًا استخدام الآلة الحثية كمولد غير متزامن، ولكنه لوحظ أن جودة القدرة الكهربائية الناتجة من هذه المولدات التي تدار بواسطة توربينة هوائية غير مرضية، وهذا بسبب سرعة الرياح المتغيرة مما يؤدي إلى أن المولد الحثي لا يستطيع إمداد الحمل بكامل القدرة المطلوبة طيلة الوقت، كما أن هناك عيبًا آخرًا مرتبطًا بهذا النوع من المولدات وهو انخفاض معامل القدرة عندما تكون سرعة الرياح منخفضة.

يهدف هذا البحث الى دراسة أداء ومدى التحكم في المولد الحثي المربوط بالشبكة بواسطة المغير الإلكتروني كرابط بين أطراف العضو الثابت للمولد الحثي والشبكة. في هذا الصدد تم استخدام قاطع التيار المتردد حيث أنه كان متوقعًا أن يعطي أداء ذا كفاءة عالية مقارنة بالمغيرات الأخرى.

في هذا البحث تم تطوير نموذج رياضي شامل للمولد الحثي المربوط بالشبكة بواسطة المغير الإلكتروني، ويأخذ هذا النموذج في الاعتبار الانفصاليات الناتجة عن عملية التبديل التي يقوم بها المغير الإلكتروني.

وتم في هذا البحث إجراء محاكاة رقمية باستخدام الحاسب الآلي للتأكد من صلاحية الأسلوب المقترح للتشغيل، وكذلك لدراسة أداء النظام المقترح في ظروف تشغيل مختلفة. ولقد تم مقارنة خصائص الأداء بإستراتيجيات التحكم المختلفة السابق بحثها لإبراز المزايا والعيوب الناتجة عن استخدام دائرة قاطع التيار المتردد كرابط بين الشبكة والمولد الحثي.

وقد وجد أن استخدام هذا المغير الإلكتروني بشكل عام يزيد القدرة على التحكم في الطاقة الكهربية الناتجة من المولد، كما أنه يحسن من جودة القدرة المنتجة.

Journal of Engineering and Computer Sciences, Qassim University, PP 19-28, Vol. 1, No. 1 (January 2008/Muharram 1429H.)

Stability Improvement of a Fully Superconducting Generator by Fuzzy Logic Control

R. A. F. Saleh
Electrical Engineering Dept., College of Engineering,
Qassim University, Qassim, Saudi Arabia
ragaeys@qec.edu.sa

(Received 28/5/2007; accepted for publication 27/11/2007)

Abstract. Fully superconducting generator (FSG) is one of the promising applications of superconductors in electric power sector. Meanwhile, transient stability of FSG is an important issue in developing this new machine. An approach is suggested in this paper for the design of a fuzzy logic governor controller (FLC) as a possible mean to improve the FSG stability under transient conditions. In this approach, unsymmetrical non-linear membership functions are used, while the number of FLC parameters to be properly designed is 15 parameters, including scaling factors for input and output variables along with widths and centers of fuzzy sets of input variables. A genetic algorithm is used to optimally choose all these parameters. Simulation results show that the proposed FLC leads to a significant improvement in the transient stability and performance of a FSG connected to an infinite-bus.

Keywords: Fully superconducting generator, Fuzzy logic control, Genetic algorithms, Transient stability.

List of Symbols

P	: Derivative operator w.r.t time.
v, i	: Voltage and current.
L_T	: Transformer self inductance.
R_T	: Transformer resistance.
L_L	: Transmission line self inductance.
R_L	: Transmission line resistance.
R_f	: Resistance of field winding.
M_{fd}	: Mutual inductance between armature and field windings.
H	: Inertia constant.
T_m	: Mechanical torque.
T_e	: Electromagnetic torque.
P_t	: Active power at generator terminal.
Q_t	: Reactive power at generator terminals.
P_o	: Boiler steam pressure.
Y	: Output of a turbine or reheat stage.
G_M, G_I	: Main and interceptor valve positions.
F	: Fractional contribution of the turbine stage into T_m.
U_g	: Governor actuating signal.
ψ	: Flux linkage.
ω_o	: Synchronous speed.
ω	: Speed deviation from synchronous speed.
δ	: Rotor angle with respect to infinite bus.
τ	: Time constant of stage.

1. Introduction

Although copper and aluminum have met most our needs for decades, the demand for conservation and more efficient use of electricity has brought renewed focus on superconductors. The application of superconductors in the field winding of a superconducting generator (SCG) appears to offer this machine a number of potential advantages such as higher efficiency, small size and weight, low synchronous reactance and hence improved steady state stability. On the other hand, the recent development of very low-loss, ultra-fine filament superconducting a.c. wires was the motive for developing another type of superconducting generators, called FSG in which both the field and armature windings are superconducting [1]. Compared with SCG, FSG has more potential to increase efficiency and decrease size and weight.

However, FSG suffers from instability when connecting to the grid [2]. Also, this machine needs current limiting devices to prevent both of the armature and the field windings from quenching during severe fault condition [3]. The characteristics of FSG connected to a power system under many kinds of conditions must be understood exactly, since power system apparatus must be highly reliable. The main difficulty in operating the FSG with a power system is its very slow response. As the field time constant is extremely large, the excitation system is not able to change quickly the field current to restore the FSG stability. Previous studies [4-6], however, have shown that the machine stability along with its transient performance could be highly improved using governor control techniques.

Recently, fuzzy logic control [7] has emerged as one of the most fruitful research areas, and many applications for enhancing power system stability have been reported in literature [8-11]. Fuzzy logic controller (FLC) is essentially a multi-parameter controller, whose performance depends on the selected shape of membership functions, rule base and scaling factors. The work described in this paper is an attempt to employ the utmost power of the well-known FLC for enhancing the FSG stability. To do so, an approach is proposed and used in the design of the controller. This approach is a rather different from that used in [6], and mainly based on unsymmetrical non-linear membership functions for input variables as explained later on in this paper.

2. System Description

A FSG-infinite bus power system, shown in Fig.1, is considered in this study. Two superconducting fault current limiters (CL1, CL2) are connected in parallel and placed between the high-voltage side of the step-up transformer and the sending-end of the transmission line. In normal operation, one of the current limiters is connected to the line, and the other is stand-by and disconnected from the line. The FSG is driven by a three-stage steam turbine, which is controlled by fast acting electro-hydraulic governors fitted to the main and interceptor valves. The mathematical model of the system under study and parameter values are given in the Appendix.

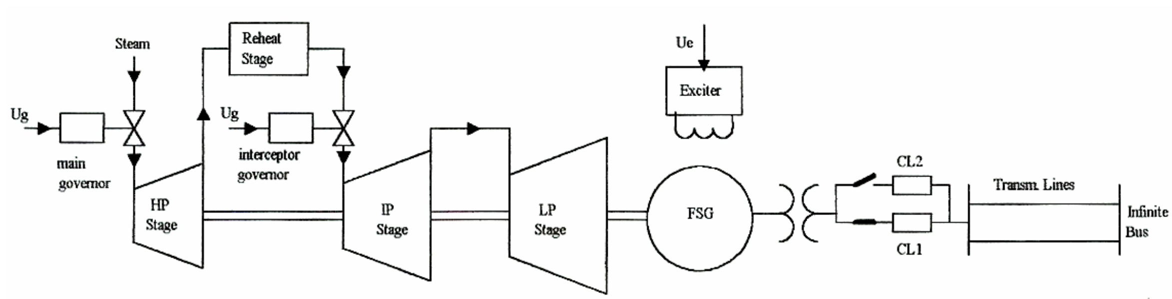

Fig. (1). Fully superconducting turbo-generator.

3. Design Procedure for a Fuzzy Logic Controller

The procedure commonly used in designing a FLC can be summarized as follows:

1. Identification of the FLC input and output variables based on understanding dynamics of the system under study.
2. Defining a universe of discourse for each variable, and a number of partitions (fuzzy subsets) within it, assigning each a linguistic label.
3. Defining a membership function for each fuzzy subset.
4. Choosing appropriate scaling factors for the input and output controller variables.
5. Deciding a defuzzification technique to convert fuzzy values into crisp values.
6. Forming the fuzzy control rules, which assign the fuzzy relationships between the input and output fuzzy subsets.

When the FLC is implemented, the following steps are performed sequentially:

1. Fuzzify the inputs to the controller.
2. Apply an inference mechanism to infer the output contributed from each rule. Then, aggregate all the rules' outputs to form an overall fuzzy output.
3. Use the defuzzification method to obtain a crisp controller output. The basic structure of a FLC is shown in Fig. (2).

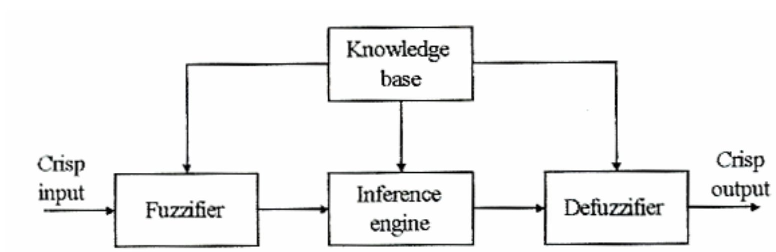

Fig. (2). Basic structure of a fuzzy logic controller.

4. Proposed Fuzzy Logic Controller

In this section, the determination of an efficient control signal, *U*, based on fuzzy logic is described. This signal is then introduced into the governor side as shown in Fig. 3, in an aim to damp the rotor oscillations after disturbances, and hence the FSG performance is improved. Speed deviation, ω, and its derivative, $\dot{\omega} = d\omega / dt$, are chosen as FLC input variables. Actually, only ω signal is measured, and from it $\dot{\omega}$ signal is computed as:

$$\dot{\omega}(k) = [\omega(k) - \omega(k-1)] / T_s \tag{1}$$

where T_s is the sampling interval. Two scaling factors, K_A and K_B, are used to map ω and $\dot{\omega}$, respectively into their predefined universes of discourse, which are divided into seven overlapping fuzzy sets; named large positive "LP", medium positive "MP", small positive "SP", zero "ZE", small negative "SN', etc. A bell-shaped membership function is assigned for each fuzzy set such that if a crisp input "*x*" belongs to a set of range [*a*-*b*] and width "*d*", then its degree of membership μ_x, in this set is defined by the following function:

$$\mu_x = \begin{cases} (2(x-a)/d)^2 & if\ a \le x \le c \\ (2(b-x)/d)^2 & if\ c \le x \le b \\ 0 & \text{else} \end{cases} \tag{2}$$

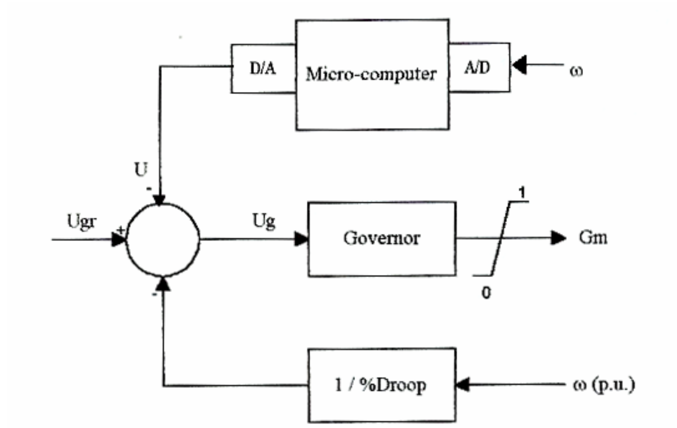

Fig. (3). The governor control system.

Table (1). Fuzzy logic control rules for FSG system.

ω \ dω/dt	**NL**	**NM**	**NS**	**ZE**	**PS**	**PM**	**PL**
NL	NS	PS	PM	PM	PM	PL	PL
NM	NS	NS	PS	PS	PM	PM	PL
NS	NM	NS	NS	PS	PS	PM	PM
ZE	NM	NM	NS	ZE	PS	PM	PM
PS	NM	NM	NS	NS	PS	PM	PM
PM	NL	NM	NS	NS	PS	PS	PS
PL	NL	NL	NM	NM	NS	NS	PS

Table 1 shows the fuzzy rules that are assigned for the FSG system [6]. Each entry in Table 1 represents a control rule, which takes the form: "IF ω is A, AND $\dot{\omega}$ is B, THEN u is C", where A, B, and C are fuzzy sets as defined by relation (2). These fuzzy rules are individually applied on the fuzzified inputs, resulting in an output fuzzy set, for each rule, clipped to a degree defined as:

$$\mu_c(u_i) = \min(\mu_A(\omega), \mu_B(\dot{\omega})) \tag{3}$$

The aggregated fuzzy outputs are converted into a single crisp value using the "weighted average" defuzzification method [12], which gives the output control signal as:

$$U = K_u \frac{\sum_{i=1}^{m} \mu_c(u_i).u_i}{\sum_{i=1}^{m} \mu_c(u_i)} \tag{4}$$

where K_u is a scaling factor, m is the number of rules giving contribution to the fuzzy output at the sampling instant considered, and u_i is the center value of the fuzzy set in consequent i.

According to the structure of FLC described above, the number of fuzzy sets, to which an input value belongs at a time, depends on how much overlap between adjacent fuzzy sets. In reference [6], equally-overlapped, triangle membership functions are used for input variables. Here, the author proposes to increase effectiveness of the FLC by adopting unsymmetrical bell-shaped functions. This could be done by using fuzzy sets with different overlaps.

5. Tuning of FLC Parameters

So far, three adjustable parameters are aforementioned, i.e., K_A , K_B and K_u. To gain more effectiveness from the proposed FLC, additional 12 adjustable parameters (six for ω fuzzy sets, and six for $\dot{\omega}$ sets) are introduced into the design. Namely, d_1, d_2, d_3 and d_4, which stand for widths of fuzzy sets (LP, MP, SP, ZE) of ω, and C_2 and C_3 which stand for centers of fuzzy sets (MP, SP) respectively. Similarly, d'_1, d'_2, d'_3, d'_4, C'_2 and C'3 are assigned for $\dot{\omega}$ fuzzy sets. Therefore, we have now 15 parameters (K_A, K_B, K_u, d_1, d_2, d_3, d_4, C_2, C_3, d_1, d_2, d'_3, d'_4, C'_2, C'_3) to be optimized simultaneously. This is a quite difficult problem to deal with using a trial-and-error approach. However, characteristics of genetic algorithm (GA) [13] make it able to solve such a complex problem. Therefore, GA with tournament selection and two-point crossover is utilized to optimally select these 15 parameters. To do so, the following performance index, J, is used:

$$J = \sum_{k=1}^{N} \{[kT.\omega(k)]^2 + [kT.\Delta G_M(k)]^2\} \quad (5)$$

where $\omega(k)$ and $\Delta G_M(k)$ are the deviations of the FSG speed and the governor valve position from their steady state values respectively. The population size in each generation of GA is chosen to be 60 strings. The crossover probability is set at 0.7 and the mutation probability is set at 0.001.

6. Simulation Results

A number of simulation studies were performed to develop and investigate the effectiveness of the proposed FLC. The performance index was evaluated, in all attempts of developing the FLC, in response to a three-phase to ground fault of 100-ms duration at the transformer high voltage terminals, with the rated output (P_t=0.9 p.u, Q_t=0.436 p.u). Variation of the performance index J with the number of generations is shown in Fig. 4. The optimal values selected by GA for K_A, K_B and K_u are 0.269, 1.235 and 1.984 respectively. The optimized fuzzy sets for ω and $\dot{\omega}$ have taken the shapes shown in Fig. 5. In Ref. [6], the fuzzy controller was compared with a conventional controller (lead compensator) and the results have shown that the fuzzy controller outperforms the conventional one. Therefore, it was seen to compare the proposed algorithm only with that of Ref. [6], while keeping the response with speed governor (SG) in the figures to show that the machine essentially need an additional control signal. The performance of the FSG system with the proposed fuzzy governor controller following a three-phase short circuit fault for 100 ms, at the operating points [(P_t, Q_t)= (0.9,0.436), (0.8, -0.2) p.u], is shown in Figs. 6 and 7, respectively. Figures 8 and 9 show the system response to a temporary (100 ms long) 5% step increase in the governor set point at the previous loading conditions. All these figures also show the system response with speed governor (SG) only, i.e. without the additional control signal, *U*. The FSG dynamic performance was analyzed using the concept of damping and synchronizing torque components. The results show that the addition of the proposed FLC improves the damping coefficient K_d by 16.5% and 150% at [(P_t, Q_t) = (0.9, 0.436), (0.8, -0.2) p.u] respectively, compared with those using another fuzzy controller [6].

The simulation results show that the proposed FLC results in a significant improvement in the FSG transient behavior and a considerable reduction in the rotor oscillations with acceptable governor valve movements. Also, although the FLC parameters are optimized for particular loading conditions and even for a particular type disturbance, they are robust and lead to more increase in the damping coefficient for other loading condition and disturbance as is shown above. Meanwhile, although the time response with the proposed approach shows slight difference when compared with that of Ref. [6], quantitive measures in terms of the performance index and damping coefficient show some improvements.

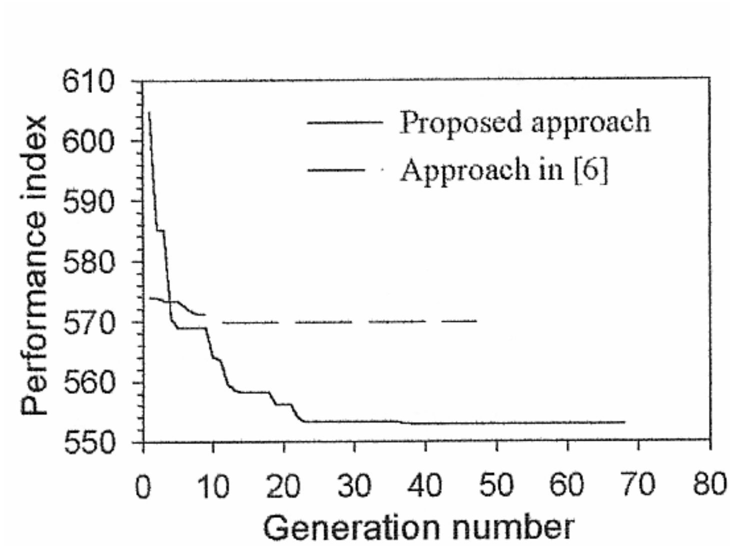

Fig. (4). Performance index convergence.

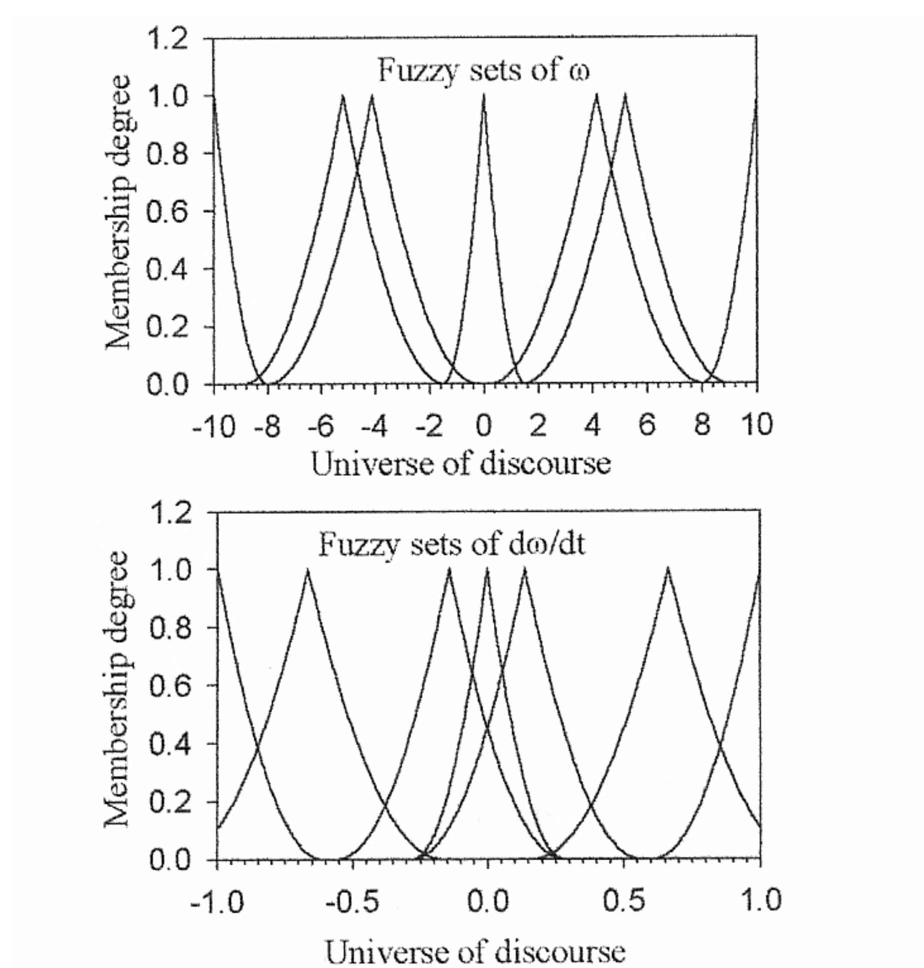

Fig. (5). Optimized fuzzy sets of ω and d ω /dt.

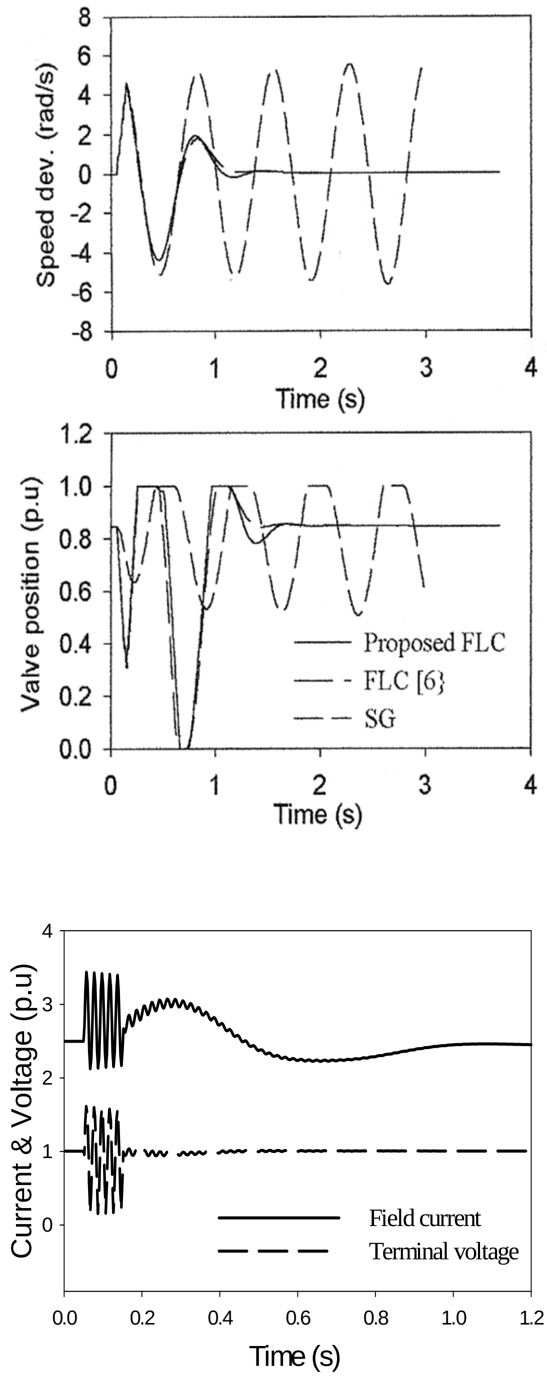

Fig. (6). Response to SC at P_t=0.9 pu, Q_t=0.436 pu.

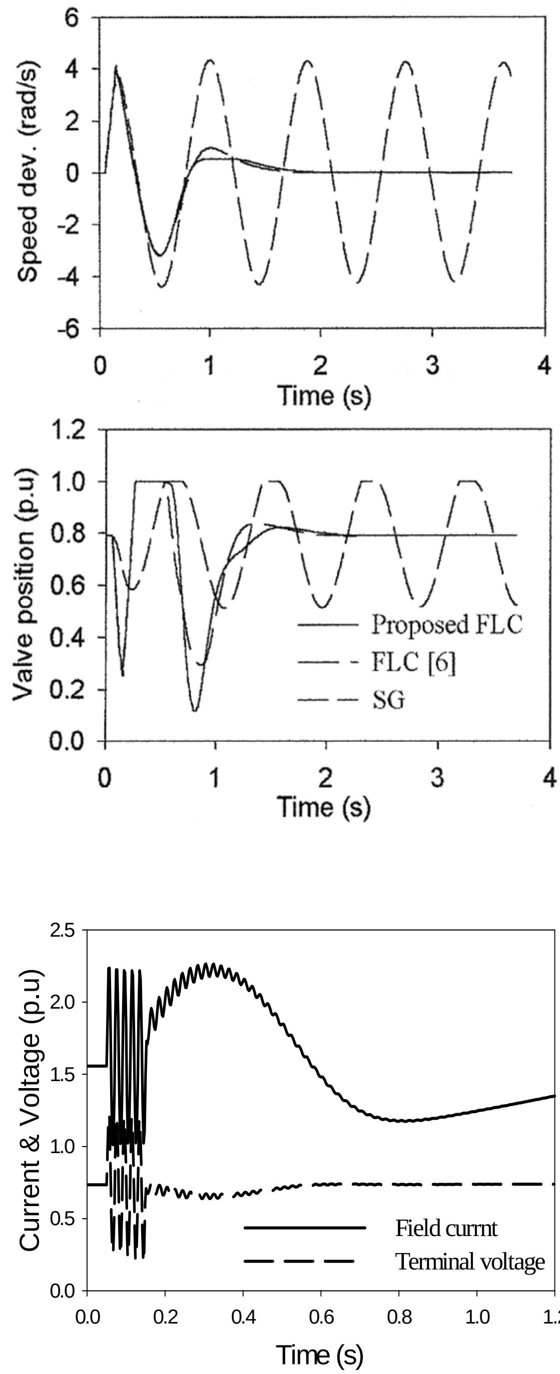

Fig. (7). Response to SC at P_t=0.8 pu, Q_t=-0.2 pu.

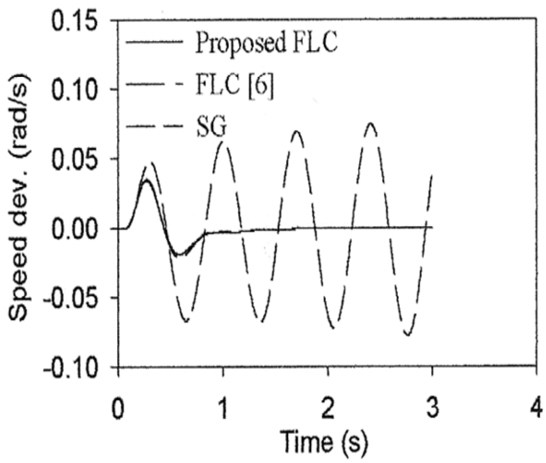

Fig. (8). Response to a pulse in U_{gr} at P_t=0.9 pu, Q_t=0.436 pu.

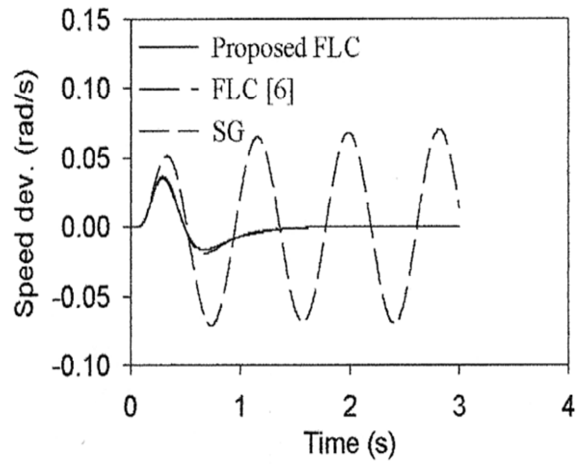

Fig. (9). Response to a pulse in U_{gr} at P_t=0.8 pu, Q_t=-0.2 pu.

7. Conclusion

This paper has presented and developed an approach for the design of a FLC for stability enhancement of a FSG. The main features of this approach are:

1. Using non-linear, unsymmetrical membership functions for the variables input to the controller.
2. Optimizing the shapes of these functions by utilizing GA to optimally assign the widths and centers of input variables' fuzzy sets. Simulation results show that the proposed controller is an efficient in enhancing FSG stability, and also provides the FSG system with more damping of the mechanical-mode oscillations than the previous FLC [6] does.

8. References

[1] Tixador, P., Prunet, Y., Vedrine, P., Laumond, Y. and Sabrie, J. L., "Electrical tests on a fully super-conducting synchronous machine," *IEEE Trans. on Magnetics*, Vol. 27, No. 2, (1991), pp.2256-2259.

[2] Tsukamoto, O., Chen, J. and Akita, S., "Stability characteristics of fully superconducting and damperless generator connected to power grid," IEEE *Trans. on Applied Superconductivity*, Vol. 3, No. 1, (1993), pp.377-380.

[3] Chen, H. and Tsukamoto, O. "Stability Characteristics of Fully Superconducting and Damperless Generator with Excitation Control in Fault Condition." *IEEE Trans. on Applied Superconductivity,* 5, No. 2 (1995), 449-452.

[4] Saleh, R.A.F. "Transient Stability Enhancement of a Fully Superconducting and Damperless Generator Using Governor Control." *Proceeding of SICE Annual Conference*, (2003), 176-181.

[5] Saleh, R.A.F. "Genetic Algorithm-tuned Fuzzy Logic-based Governor Controller for a Fully Superconducting Generator." *Proceeding of the ninth MEPCON*, 1 (2003), 125-130.

[6] Bishr, M.A. and Saleh, R.A.F. "Design of a Fuzzy Logic Controller for a Fully Superconducting Generator Using a Genetic Algorithm." *Engineering Research Journal*, 27, No. 2 (2004), 151-157.

[7] Lee, C.C. "Fuzzy Logic in Control Systems: Fuzzy Logic Controller - Part I, Part II." *IEEE Trans. on Systems, Man, and Cybernetics*, 20, No. 2 (1990), 404-435.

[8] Hassan, M.A.M.; Malik, O.P. and Hope, G.S. "A Fuzzy Logic Based Stabilizer for a Synchronous Machine." *IEEE Trans. on Energy Conversion*, 6, No. 3 (1991), 407-413.

[9] Hsu, Y.Y. and Cheng, C.H. "A Fuzzy Controller for Excitation Control." *IEEE Trans. on Systems, Man, and Cybernetics,* 23, No. 2 (1993), 532-539.

[10] Hiyama, T. "Robustness of Fuzzy Logic Power System Stabilizers Applied to Multi-machine Power System." *IEEE Trans. on Energy Conversion*, 9, No. 3 (1994), 451-459.

[11] El-Metwally, K.A. and Malik, O.P. "Fuzzy Logic Power System Stabilizer." *IEE Proc., Pt. C.,* 142, No. 3 (1995), 277-281.

[12] Ross, T.J. *Fuzzy Logic with Engineering Applications.* New York: McGraw-Hill Inc., 1995.

[13] Goldberg, D.E. *Genetic Algorithms in Search, Optimization, and Machine Learning.* USA: Addison-Wesley Publishing Co., 1989.

9. Appendix

The mathematical model of the FSG:

$$p\psi_f = \omega_o[v_f - i_f R_f]$$

$$p\psi_d = \omega_o[v_d + \psi_q] + \psi_q \omega$$

$$p\psi_q = \omega_o[v_q - \psi_d] - \psi_d \omega$$

$$p\delta = \omega$$

$$p\omega = \frac{\omega_o}{2H}[T_m - T_e]$$

$$T_e = \psi_d i_q - \psi_q i_d$$

The mathematical model of the turbine and governor system:

$$pY_{HP} = (G_M P_o - Y_{HP}) / \tau_{HP}$$

$$pY_{RH} = (Y_{HP} - Y_{RH}) / \tau_{RH}$$

$$pY_{IP} = (G_I Y_{RH} - Y_{IP}) / \tau_{IP}$$

$$pY_{LP} = (Y_{IP} - Y_{LP}) / \tau_{LP}$$

$$T_m = F_{HP} Y_{HP} + F_{IP} Y_{IP} + F_{LP} Y_{LP}$$

$$pG_M = (U_g - G_M) / \tau_{GM}$$

$$pG_I = (U_g - G_I) / \tau_{GI}$$

Parameters of the system studied are:
S=1100 MVA, L_f=0.77, L_d=L_q=0.53, M_{fd}=0.53, R_f=0.0000029,R_T=0.003, X_T=0.15, R_L=0.0075, X_L=0.195, H=3 kW.s/kVA, τ_{GM} =τ_{GI} =0.1, τ_{HP} =0.1, τ_{RH} =10, τ_{IP} =τ_{LP} =0.3, P_o = 1.2 p.u, F_{HP} = 0.26, F_{IP} = 0.42, F_{LP} = 0.32

س   استقرار مولد فائق التوصيل بواسطة التحكم ا نطقي الغيمي

رجائي عبد الفتاح صا

قسم ا ندسة الكهربائية، كلية ا ندسة- جامعة القصيم

القصيم- ا ملكة العربية السعودية

(قُدم للنشر في ٢٨/٥/٢٠٠٧م ؛ وقُبل للنشر في ٢٧/١١/٢٠٠٧م)

ملخص البحث. تعتبر المولدات الفائقة التوصيل أحد التطبيقات الواعدة للموصلات الفائقة التوصيل في قطاع القوى الكهربية. كذلك تعد دراسة استقرار هذه المولدات عند تعرضها لاهتزازات في الشبكة الكهربية من الأمور الهامة في تطويرها. ونظرًا لأن الثابت الزمني لملفات المجال الفائقة التوصيل كبير جدًّا ، فإن الوسيلة الأساسية المتاحة لتحسين الاستقرار العابر لهذه المولدات هي ضبط الحاكم. يقدم هذا البحث طريقة فعالة لتصميم ضابط غيمي ، وذلك لإخماد الذبذبات الميكانيكية وتحسين الاستقرار لمولد فائق التوصيل متصل بنظام قوي لانهائي في الظروف العابرة. تم في هذه الدراسة استخدام دوال عضوية غير خطية وغير متماثلة الاتساع لكل من الانحراف في سرعة المولد ومعدل التغير في السرعة ، واللذان يمثلان المتغيرات الداخلة للضابط الغيمي. تضم مجموعة ثوابت الضابط ١٥عنصرًا يجب اختيارها بعناية. تم استخدام طريقة الخوارزم الوراثي لتحديد القيم المثلى لثوابت الضابط. توضح نتائج المحاكاة أن الضابط المقترح يؤدي إلى تحسن جيد في أداء واستقرار النظام المدروس على مدى واسع من أحوال التشغيل.

Journal of Engineering and Computer Sciences, Qassim University, PP 29-42, Vol. 1, No. 1 (January 2008/Muharram 1429H.)

A Comparative Study of PI/PID Classical and Intelligent Tuning Methods

Adel Abdennour* and Fahd A. Alturki**
Department of Electrical Engineering, College of Engineering,
King Saud University, P.O. Box 800, Riyadh, 11421, Saudi Arabia
** adnnour@ksu.edu.sa, ** falturki@ksu.edu.sa*

(Received 27/5/2007; accepted for publication 15/12/2007)

Abstract. Proportional-plus-Integral-plus-Derivative (PID) controllers are widely used in the industrial world. Due to their popularity, a large number of methods have been suggested in the literature to tune them. This paper summarizes and compares seven different PID tuning techniques (in addition to some of their variations). The comparison includes some of the early approaches; namely, Ziegler-Nichols methods, minimum error, phase and gain margins, pole allocation, and LQR. Modern techniques (fuzzy logic and genetic algorithm) are also used and assessed. The seven tuning alternatives are evaluated in terms of their performance, complexity and flexibility.

Keywords: PID tuning, Ziegler-Nichols, Minimum integral error, Genetic algorithms, Fuzzy logic.

1. Introduction

Proportional-plus-Integral-plus-Derivative (PID) controllers are the most commonly used controllers in the industrial world. In fact, according to a 1993 study conducted by JEIMA (Japan Electric Instruments Manufacturers Association), it was found that 91.3% of the 2978 surveyed industrial applications use PID [1-3]. The success and longevity of PID controllers were characterized in a recent workshop, where over 90 papers dedicated to PID research including software packages, hardware modules and patented PID tuning rules were presented [2]. Such facts should not be too surprising because PID controllers are easier to understand than other techniques. In addition, due to their simple structure they are relatively easier to implement.

The most common form of the PID is represented by the transfer function:

$$G_c(s) = K_p + \frac{K_i}{s} + K_d s \tag{1}$$

Other equivalent forms are often used such as:

(non-interacting) $$G_c(s) = K_c[1 + \frac{1}{T_i s} + T_d s] \tag{2}$$

and

(interacting) $$G_c(s) = K_c^{'}[T_d^{'} s + 1][1 + \frac{1}{T_i^{'} s}] \tag{3}$$

Transformation from one form to another is straightforward.

Owing to the popularity of this control method, a number of approaches have been developed to determine the PID parameters for single-input-single-output (SISO) systems. Among the more vastly used are Ziegler-Nichols method, minimum integral error, pole allocation, gain and phase margins, optimal control, genetic algorithms (GA), and fuzzy logic.

Basically, most patented identification and tuning methods are process-engineering oriented and appear ad hoc. In addition, it seems that the major difficulty appears in delivering an optimal transient response due to unexpected difficulties in setting optimal terms and, consequently, artificial intelligence is incorporated in software or onboard algorithms to augment simple PID structures [1]. In [4], a hybrid fuzzy-GA PID controller was proposed toward an optimal design. The salient feature of this approach is that it combines the fuzzy gain scheduling method and a fuzzy proportional–integral-derivative (PID) controller to solve the non-linear control problem.

In this paper, seven tuning techniques are compared and evaluated in terms of performance, ease of design and flexibility. The comparison is based on the application to a generic fourth order model with a reasonable complexity.

2. Ziegler-Nichols Tuning Methods

This tuning method is considered one of the early attempts to PID tuning and yet it is still widely used. There are few variations to this approach among which are: Ziegler-Nichols method based on ultimate gain and period, Ziegler-Nichols method based on reaction curve, and refined Ziegler method.

2.1. Ziegler-Nichols method using ultimate gain and period

This method was proposed by J. Ziegler and N. Nichols around 1940. The ultimate gain K_u and ultimate period T_u are used to tune the control parameters for the quarter-dacay ratio (QDR) response in which each oscillation has an amplitude that is one-fourth of the previous one. The ultimate gain K_u is the gain at which the loop oscillates with constant amplitude when the process is under closed-loop proportional control and the ultimate period T_u is the period of these oscillations.

For the PID in forms (2) and (3), the Ziegler-Nichols QDR tuning formulas based on K_u and T_u are [5]:

$$K_c = 0.75K_u \qquad T_i = T_u / 1.6 \qquad T_d = T_u / 10 \tag{4}$$
$$K_c^{'} = 0.6K_u \qquad T_i^{'} = T_u / 2 \qquad T_d^{'} = T_u / 8$$

In addition to its simplicity, this method can produce reasonably fast responses for most industrial loops (usually accompanied with excessive overshoot if not fine-tuned). However, many processes do not permit operation near marginal stability and, hence, experimental evaluation of K_u and T_u is not practical. Even in cases where operation in marginal stability is possible, some loops may not exhibit sustained oscillation with proportional control (first-order systems as an obvious example). An additional drawback of this method is that the ultimate gain and period do not give insight into which control factor could be modified to improve performance.

2.2. Ziegler-Nichols method using process reaction curve

This method alleviates the drawbacks of relying on the ultimate and gain period. It assumes that the process is represented by a first-order plus dead-time model, i.e.:

$$G(s) = \frac{Ke^{-Ls}}{\tau s + 1} \tag{5}$$

where
K : the process steady-state gain
L : the effective process dead-time, and
τ : the effective process time-constant.
Based on this model, the alternative tuning formulas for QDR response is given by:

$$K_c^{'} = \frac{1.2\tau}{KL} \qquad T_i^{'} = 2L \qquad T_d^{'} = 0.5L \tag{6}$$

This alternative method offers acceptable performance for many control loops while being fairly simple. However, it still can't overcome the excessive overshoot unless fine-tuned. In addition, it depends on modeling the plant as a first-order plus dead time which may not always be possible.

2.3. Refined Ziegler-Nichols method

This method is also developed for the first-order plus dead-time model of the form given by (5). The tuning formulas for PI control (form (2) with $T_d = 0$) are given by [6]:

$$K_c = \frac{5K_u}{6}\left[\frac{12 + K_u K}{15 + 14K_u K}\right] \tag{7}$$

$$T_i = \frac{T_u}{5}\left[\frac{4}{15}K_u K + 1\right] \tag{8}$$

This method gives an almost consistent phase margin of 50 degrees but a varying gain margin of about six for $(L/\tau) = 0.2$ decreasing to three for $(L/\tau) = 1.0$. The performance is consistent with about 10% overshoot [7].

3. PID Tuning for Minimum Error Integrals

This approach is based on minimizing either the integral of the absolute error (IAE) or the integral of the absolute of the product of time and error (IATE). This method uses first-order plus dead-time model parameters described by (5) and the PID takes the non-interactive form given by (2). It is suitable only for processes with (L/τ) in the range (0.1 to 1.0).

3.1. Tuning by minimum IAE

The minimum IAE tuning formulas for set-point changes are given by [8]:

$$K_c = \frac{1.086}{K}\left(\frac{L}{\tau}\right)^{-0.869} \quad (9)$$

$$T_i = \frac{\tau}{0.74 - 0.13(L/\tau)} \quad (10)$$

$$T_d = 0.348\tau\left(\frac{L}{\tau}\right)^{0.914} \quad (11)$$

3.2. Tuning using minimum IATE

For minimum IATE, the parameters are given by [8]:

$$K_c = \frac{0.965}{K}\left(\frac{L}{\tau}\right)^{-0.855} \quad (12)$$

$$T_i = \frac{\tau}{0.796 - 0.147(L/\tau)} \quad (13)$$

$$T_d = 0.308\tau\left(\frac{L}{\tau}\right)^{0.929} \quad (14)$$

4. PI Tuning Using Phase and Gain Margins

This method is based on the gain and phase margins to tune PI parameters (form (2) with $T_d = 0$). For plants that can be modeled by the first-order plus dead-time structure given by (5), the tuning formulas are [7]:

$$\omega_p = \frac{A_m\Phi_m + \frac{\pi}{2}A_m(A_m - 1)}{(A_m^2 - 1)L} \quad (15)$$

$$K_c = \frac{\omega_p \tau}{A_m K} \quad (16)$$

$$T_i = \frac{1}{\left(2\omega_p - \frac{4\omega_p^2 L}{\pi} + \frac{1}{\tau}\right)} \quad (17)$$

where (A_m, Φ_m) is a specified gain and phase margin pair and ω_p is the phase crossover frequency.

5. PID Tuning Based on Pole Allocation

This method assumes that the plant is described by a second-order plus dead time model in the form:

$$\hat{G}(s) = \frac{e^{-sL}}{as^2 + bs + c} \tag{18}$$

where a, b, c and L are unknowns to be determined. Unlike the first-order structure given by (5), the model can have real or complex poles. Therefore, it is suitable for representing monotonic or oscillatory processes while still being of sufficiently low order. To determine the four unknowns, it is sufficient to match the actual process, $G(s)$, to the model given by (18) at two non-zero frequencies, e.g. $s=j\omega_c$ and $s=j\omega_b$, where $\angle G(j\omega_c)=-\pi$ and $\angle G(j\omega_b)=-(\pi/2)$, such that $G(j\omega_c) = \hat{G}(j\omega_c)$ and $G(j\omega_b) = \hat{G}(j\omega_b)$. The a, b and c values can then be calculated using [9]:

$$a = \frac{1}{\omega_c^2 - \omega_b^2}\left[\frac{\sin(\omega_b L)}{|G(j\omega_b)|} + \frac{\cos(\omega_c L)}{|G(j\omega_c)|}\right] \tag{19a}$$

$$b = \frac{\sin(\omega_c L)}{\omega_c |G(j\omega_c)|} \tag{19b}$$

$$c = \frac{1}{\omega_c^2 - \omega_b^2}\left[\frac{\omega_c^2 \sin(\omega_b L)}{|G(j\omega_b)|} + \frac{\omega_b^2 \cos(\omega_c L)}{|G(j\omega_c)|}\right] \tag{19c}$$

A good approximation for L is the smaller absolute root of the following quadratic equation:

$$p(\omega_c^2 - \theta\omega_b^2)L^2 + (q\omega_c - \theta r\omega_b)L - \theta = 0 \tag{20a}$$

where

$$p = \left(8/\pi^2\right)\left(1-\sqrt{2}\right) \qquad q = \left(2/\pi\right)\left(2\sqrt{2}-1\right)$$
$$r = \left(2/\pi\right)\left(2\sqrt{2}-3\right) \qquad \theta = \left(\omega_c\,|G(j\omega_c)|\right)/\left(\omega_b\,|G(j\omega_b)|\right) \tag{20b}$$

According to the equivalent time constant principle, we have:

$$\frac{1}{\tau_0} = \begin{cases} \dfrac{c}{\sqrt{b^2 - 2ac}} & b^2 - 4ac \ge 0 \\ \dfrac{b}{2a} & b^2 - 4ac < 0 \end{cases} \tag{21}$$

The damping ratio ξ_0 of the open-loop plant is defined as:

$$\xi_0 = \begin{cases} \dfrac{b}{2\sqrt{ac}} & b^2 - 4ac < 0 \\ 1 & b^2 - 4ac \geq 0 \end{cases} \quad (22)$$

For the PID controller of form (1), using pole-allocation method, the controller parameters are found to be [9]:

$$\begin{bmatrix} K_p \\ K_i \\ K_d \end{bmatrix} = k \begin{bmatrix} b \\ c \\ a \end{bmatrix} \quad (23)$$

where k is a gain chosen so that the controller zeros cancel the model poles. For $\xi_0 > 0.7071$ or $L/\tau_0 < 0.15$ or $L/\tau_0 > 1$,

$$k = \frac{0.5}{L} \quad (24a)$$

For $\xi_0 \leq 0.7071$ or $0.15 \leq L/\tau_0 \leq 1$,

$$k = \min\left\{ \frac{1}{\tau_0} e^{-(L/\tau_0)}, \frac{1}{eL} \right\} \quad (24b)$$

6. PI/PID Tuning on the Basis of LQR Approach

In this method [10], the PI parameters are tuned on-line according to the LQR method (optimal control). A criterion for selecting the state and control weighting matrices (*Q* and *R)* that will lead to a specified natural frequency (ω_n) and damping ratio (ξ) of the closed-loop system is given. For the first-order plus delay model given in (5) and a PI controller model G_c given by Eq. (1) with $K_d = 0$, the algorithm starts by choosing the closed loop ω_n and ξ, and setting *R*=1. Then, the PI parameters are tuned according to the time-varying formulas [10]:

- For $0 \leq t < L$

$$K_i(t) = R^{-1}\bar{b}\left[p_{12} f_{11}(t) + p_{22} f_{21}(t)\right] \quad (25a)$$

$$K_p(t) = R^{-1}\bar{b}\left\{ \frac{1}{a} p_{12} f_{11}(t) + \frac{1}{a} p_{22} f_{21}(t) + \left[p_{12} f_{12}(t) - \frac{1}{a} p_{12} f_{11}(t) + p_{22} f_{22}(t) - \frac{1}{a} p_{22} f_{21}(t) \right] e^{-a(L-t)} \right\} \quad (25b)$$

- For $t \geq L$

$$K_i(t) = R^{-1}\bar{b}\left[p_{12} f_{11}(L) + p_{22} f_{21}(L)\right] \quad (26a)$$

$$K_p(t) = R^{-1}\bar{b}\left[p_{12} f_{12}(L) + p_{22} f_{22}(L)\right] \quad (26b)$$

where p_{12} and p_{22} are elements of the solution P of the Riccati equation, $\bar{a} = 1/\tau$, $\bar{b} = K/\tau$, and f_{ij} are some time-varying functions related to both the open-loop and closed-loop state-transition matrices [10]. In some cases, this method can be extended to second-order models simply by choosing one zero of the PID so that it cancels one real pole of the plant. By doing so, the problem is reformulated into designing a PI controller for a first order plus delay model as described above. It is apparent that this method is critical to the choice of ω_n and ξ or $\omega_n L$.

7. PID Tuning Using Genetic Algorithms

Genetic Algorithms (GA) are powerful derivative-free optimization tools that require no specific details about the optimized system or function. The only link between the GA and the problem being solved is the fitness function, which is chosen by the designer to reflect how good the solution is. The candidate solution is coded in a binary string called chromosome. The algorithm performs the three classical operators: reproduction, crossover, and mutation in search of the best chromosome (the fittest one) [11-14].

A binary number of *6n* bits is used to code any given candidate solution (*2n* bits to represent K_p, *2n* bits to represent K_i, and *2n* bits to represent K_d). For each of the three gains, *n* bits are used to code the decimal part and the other *n* bits are used to code the fraction part. The number of bits (*n*) is chosen according to the expected magnitude of the gains and the desired resolution. For cases where the PID gains are not expected to be of magnitudes much higher than 100, a resolution of seven bits is enough with reference to the derivative time constant, i.e. $T_i = \alpha T_d$. To obtain the PID in the standard form given by (1), the following simple conversion is made:

$$K_p = K_c, \qquad K_d = K_c T_d, \qquad K_i = K_p^2 \big/ (\alpha K_d) \tag{27}$$

8. PID Tuning Using Fuzzy Logic

This approach is also known as fuzzy gain scheduling of PID controllers. In this scheme, the controller parameters are determined based on the current error *e(t)* and its first derivative $\dot{e}(t)$. The basic structure of the PID is the same as the form given by (2). The integral time constant is determined.

For convenience, K_p and K_d are normalized into the range between zero and one using the following linear transformation:

$$\begin{aligned} K'_p &= (K_p - K_{p,\min}) \big/ (K_{p,\max} - K_{p,\min}) \\ K'_d &= (K_d - K_{d,\min}) \big/ (K_{d,\max} - K_{d,\min}) \end{aligned} \tag{28a}$$

The ranges of the gains are: $K_{p,min}$=0.32K_u, $K_{p,max}$=0.6K_u, $K_{d,min}$=0.08K_uT_u, and $K_{d,max}$=0.15K_uT_u where K_u and T_u are the gain and period of oscillation at the stability limit under proportional control [15, 16].

The parameters K'_p, K'_d, and α are determined by a set of fuzzy rules taking the error and its derivative as inputs. The actual gains are then obtained using:

$$\begin{aligned} K_p &= (K_{p,\max} - K_{p,\min}) K'_p + K_{p,\min} \\ K_d &= (K_{d,\max} - K_{d,\min}) K'_d + K_{d,\min} \\ K_i &= K_p^2 \big/ (\alpha K_d) \end{aligned} \tag{28b}$$

9. Illustrative Example

To compare the seven aforementioned PID tuning methods, a fourth-order plant is considered. The plant has sufficient complexity for the purpose of evaluation. The transfer function of the process to be controlled is given by:

$$G(s) = \frac{1}{(s^2 + s + 1)(s + 2)^2} e^{-0.1s} \tag{29a}$$

Approximating (29a) by a first-order plus delay, by matching the responses at two points in the region of high rate of change in the reaction curve, yields:

$$G(s) = \frac{0.25}{1.2s + 1} e^{-1.45s} \tag{29b}$$

From this first-order model, it can be easily deduced that the gain K=0.25, the time constant τ =1.2, and delay L = 1.45 sec. At marginal stability (under proportional control), the ultimate gain and ultimate period are K_u=7.056 and T_u = 5.185 sec., respectively. The PID gains for the three variants of Ziegler method and the two variants of the minimum error method are readily calculated from the equations presented in Sections 1 and 2. It is noted here that $L/\tau > 1$. This "violation" may deteriorate the performance of the PI/PID controllers designed based on the first-order model.

To obtain the PI gains using the method based on phase and gain margins, the values of these margins (A_m and Φ_m) need to be specified. Such choice is critical to the performance of the PI controller. This method replaces the problem of finding the proper controller gains by the problem of finding the proper margins. For this example, A_m is set to 3dB and Φ_m to 60 degrees. These values are judged as typical, albeit other values are likely to produce better results.

For the pole-allocation method, the approximate model given by (18) is found using (19) and (20). The model parameters are determined to be: a = 5.6504, b = 4.9513, c = 4.5006 and L = 0.8355. From (24), the value of k was found to be 0.3034. The PID parameters are easily calculated using (23).

To find the PID gains using the LQR method and as recommended in Section 5, one zero of the PID is chosen to be at -2 to cancel one real pole of the plant so that the transfer function becomes:

$$\overline{G}(s) = \frac{1}{(s^2 + s + 1)(s + 2)} e^{-0.1s} \tag{30}$$

The design process becomes of PI (instead of PID). $\overline{G}(s)$ is further reduced to:

$$\hat{\overline{G}}(s) = \frac{0.443}{(s + 0.8865)} e^{-0.968s} \tag{31}$$

Comparing to (5), we deduce that $\tau = 1/0.8865$, $K = 0.443/0.8865$, and L = 0.968. Choosing $\omega_n = 0.5$, and $\eta = 0.71$, $K_i(t)$ and $K_p(t)$ can be readily evaluated using (25) and (26).

The classic genetic algorithm is designed to optimize the PID parameters so that the response of the process is as close as possible to a chosen target. The response of a prototype second-order system with $\xi = 0.7071$ and $\omega_n = a\cos(\xi) / \left(L\sqrt{1-\xi^2}\right)$ is chosen as such a target. For the GA, the knowledge of the model is not needed. However, a fitness function reflecting the performance of the system is crucial. A common fitness function can be expressed in terms of IATE, i.e.:

$$f(t) = \frac{1}{\int |te(t)| dt} \tag{32}$$

The population size, number of generations, mutation rate, and cross-over rate are, respectively, 20, 30, 0.05 and 0.5 the results can be obtained after just 30 iterations.

To tune the PID control using fuzzy gain scheduling, the fuzzy inputs (the error and its first derivative) are partitioned into five triangular fuzzy membership functions (MF's): Negative Big (NB), Negative Small (NS), Zero (Z), Positive Small (PS), and Positive Big (PB). Only two fuzzy MF's are needed for the normalized output gains (K_p' and K_d'). They are named Small (S) and Big (B). For the third fuzzy output (α), three triangular MF's representing the value of the output (2, 3 or 4) are chosen. The membership functions are shown in Fig. 1, and the rule base for the fuzzy gain scheduling is given in Tables 1, 2 and 3.

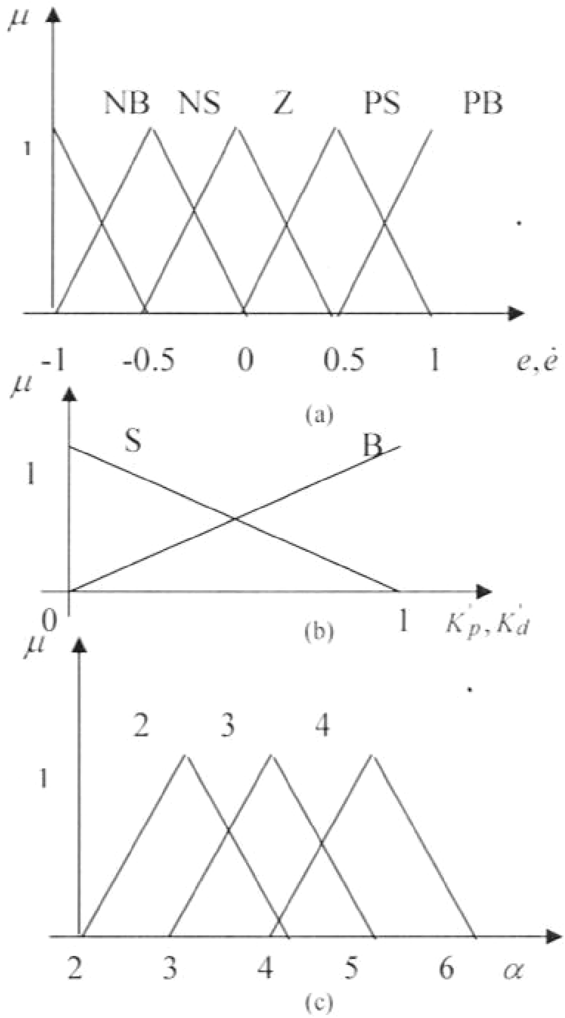

Fig. (1). Fuzzy membership functions.

Table (1). Fuzzy tuning rules for Kp'.

$\dot{e}(t)$ across columns; $e(t)$ down rows.

e(t)	NB	NS	Z	PS	PB
NB	B	B	B	B	B
NS	S	B	B	B	S
Z	S	S	B	S	S
PS	S	B	B	B	S
PB	B	B	B	B	B

Table (2). Fuzzy tuning rules for K_d'.

$\dot{e}(t)$ across columns; $e(t)$ down rows.

e(t)	NB	NS	Z	PS	PB
NB	B	S	S	S	B
NS	B	B	S	B	B
Z	B	B	B	B	B
PS	B	B	S	B	B
PB	B	S	S	S	B

Table (3). Fuzzy tuning rules for α.

$\dot{e}(t)$ across columns; $e(t)$ down rows.

e(t)	NB	NS	Z	PS	PB
NB	3	2	2	2	3
NS	3	3	2	3	3
Z	4	3	3	3	4
PS	3	3	2	3	3
PB	3	2	2	2	3

The PID gains for all approaches presented in this paper are summarized in Table 4. An evaluation in terms of percent maximum overshoot (% O.S.) and the settling time (T_s) based on the 5% criterion is summarized in Table 5. A step response comparison is illustrated in Figs. 2, 3 and 4.

Table (4). Summary of the PID gains.

	Z-N Ultim. gain	Z-N React. curve	Refined Ziegler	IAT	ITAE	Phase and gain margins	Pole allocation	LQR	GA	Fuzzy
K_p	5.292	4.965	2.039	3.685	3.284	1.733	1.504	N/A*	3.140	N/A*
K_I	1.633	1.370	1.377	1.790	1.692	1.440	1.367	N/A*	1.800	N/A*
K_d	2.744	2.880	N/A+	1.830	1.447	N/A+	1.717	N/A*	3.950	N/A*

+ Only PI is considered here
* Time varying gains

Table (5). Evaluation in terms of overshoot and 5% settling time.

	Z-N Ultimate gain	Z-N Reaction curve	Refined Ziegler	IAT	ITAE	Phase and gain margins	Pole allocation	LQR	GA	Fuzzy
% O.S.	18.0	8.6	10.6	18.3	16.2	14.7	4.9	4.6	3.7	0.0
T_s (sec)	12.3	12.3	12.5	10.6	10.9	13.2	4.8	10.5	3.6	9.4

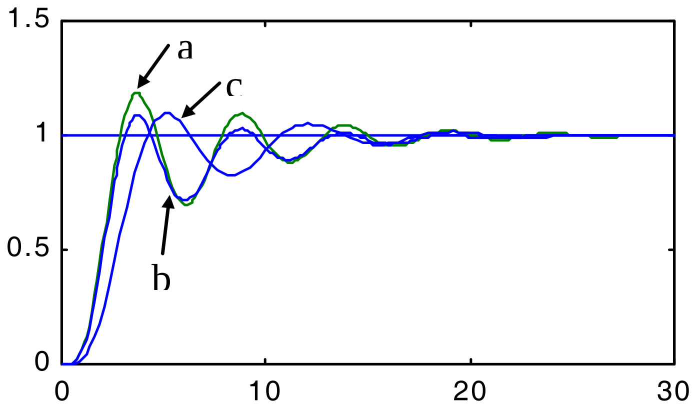

Fig. (2). Step response: a) Zigler-Nichols ultimate gain. b) Zigeler-Nichols (reaction curve). c) Refined Ziegler.

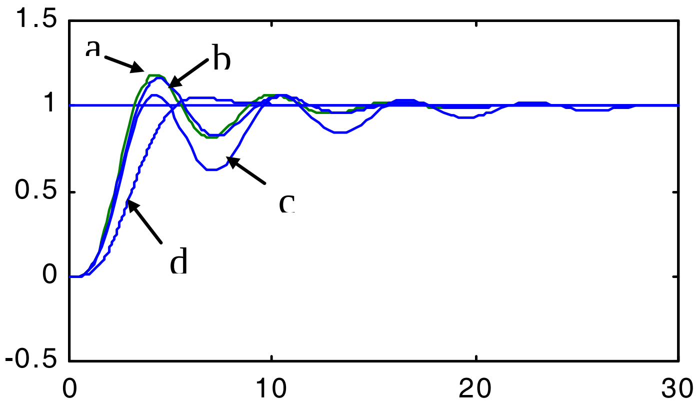

Fig. (3). Step response: a) IAE. b) ITAE. c) Phase and gain margins. d) Pole allocation.

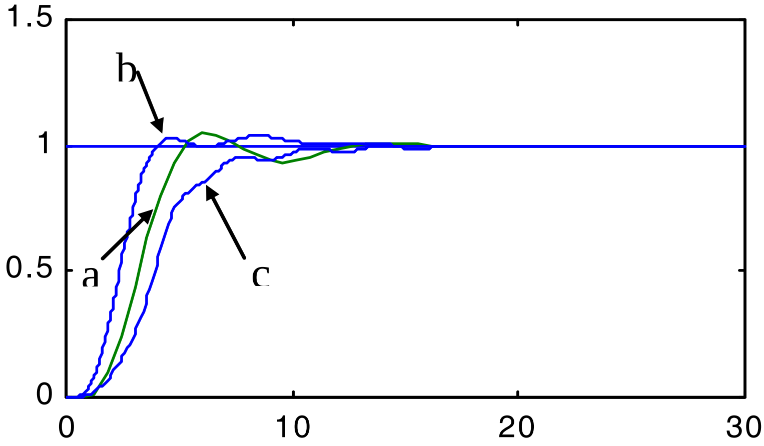

Fig. (4). Step response: a) LQR. b) GA. c) Fuzzy logic.

10. Conclusions

A comparative study of a number of PI/D tuning methods has been conducted. Seven different techniques were presented and evaluated. A fourth-order system was used to evaluate the performance of the different techniques. It was observed that the earlier techniques (e.g. Ziegler-Nichols, minimum error, phase and gain margins) are the easiest in terms of design. However, they share the drawback of excessive overshoot. In addition, they require a first-order model of the system which may not always be possible. Moreover, these techniques are not flexible. The design has to be repeated for any variations in the model.

The optimal control approach and fuzzy logic produce time-varying gains, which should offer better performance in comparison to fixed gains. However, the additional complexity of the design is not compensated by any exceptional improvement in the performance.

The pole allocation method provides a good response (in terms of speed and overshoot) while being straightforward. Nevertheless, its design process is little lengthier and less flexible than most of the other alternatives.

Out of the different approaches presented in this work, the genetic algorithm stands out as the one that offers the best PID gains with no specific knowledge of the plant and no additional complexity in the design process. More importantly, the algorithm can be used for any model as long as the fitness function reflects the desired performance.

11. References

[1] Nozaka, Y. "Trend of New Control Theory Application in Industrial Process Control (Survey)." *Proceedings of the 12th World Congress of IFAC,* Sydney, Australia, Vol. 6, (July 18-23, 1993), 51-54.

[2] Li, Y.; Ang, K. H. and Ching, G. C. Y. "Patents, Software, and Hardware for PID Control: An Overview and Analysis of the Current Art." *IEEE Control Systems Magazine,* February 2006, 42-54.

[3] Ang, K. H.; Chong, G. and Li, Y. "PID Control System Analysis, Design, and Technology." *IEEE Transactions on Control Systems Technology,* 13, No. 4 (July 2005), 559-576.

[4] Sun, Y. L. and Er, M. J. "Hybrid Fuzzy Control of Robotics Systems." *IEEE Transactions on Fuzzy Systems,* 12, No. 6 (December 2004), 755-765.

[5] Ziegler, J. G. and Nichols, N. B. "Optimum Setting for Automatic Controllers." *ASME Trans.,* 64, No. 11 (1940), 759-768.

[6] Hang, C. C.; Astrom, K. J. and Ho, W. K. "Refinement of the Ziegler-Nichols Tuning Formula." *Proceedings of the Inst. Elect. Eng., Part D,* 138, No. 2 (March 1991), 111-118.

[7] Ho, W. K.; Hang, C. C. and Cao, L. S. "Tuning of PID Controllers Based on Gain and Phase Margins Specifications." *Automatica,* 31 (1994), 497-502.

[8] Smith, C. A. and Corripio, A. B. *Principles and Practice of Automatic Process Control*. New York: Wiley, 1985.

[9] Wang, Q.; Lee, T.; Fung, H.; Bi, Q. and Zhang, Y. "PID Tuning for Improved Performance." *IEEE Transactions on Control Systems Technology,* 7, No. 4 (1999), 457-465.

[10] He, J. B.; Wang, Q. G. and Lee, T. H. "PI/PID Controller Tuning via LQR Approach." *Proceedings of the 37th IEEE Conference on Decision and Control,* (1998), 1177-1182.
[11] Goldberg, D. E. *Genetic Algorithms in Search, Optimization, and Machine Learning.* Addison-Wesley, 1989.
[12] Holland, J. H. *Adaptation in Natural and Artificial Systems.* MIT Press, 1992.
[13] Koza, J. *Genetic Programming: On the Programming of Computers by Means of Natural Selection.* MIT Press, 1992.
[14] Davis, L. (Ed.). *Genetic Algorithms and Simulated Annealing.* Morgan Kaufmann, 1987.
[15] Zhao, Z.; Tomizuka, M. and Isaka, S. "Fuzzy Gain Scheduling of PID Controllers." *IEEE Transactions on Systems, Man, and Cybernetics,* 23, No. 5 (1993), 1392-1398.
[16] Wang, L. *A Course in Fuzzy Systems and Control.* New Jersey: Prentice Hall, 1997.

دراسة مقارنة لطرق التوليف التقليدية والذكية للمتحكمات النسبية والتكاملية أو النسبية والتكاملية والتفاضلية

عادل عبد النور، فهد التركي

قسم الهندسة الكهربائية- كلية الهندسة- جامعة الملك سعود

الرياض- المملكة العربية السعودية

(قُدم للنشر في ٢٠٠٧/٥/٢٧م ؛ وقُبل للنشر في ٢٠٠٧/١٢/١٥م)

ملخص البحث. تعتبر المتحكمات النسبية والتكاملية والاشتقاقية (PID) من أكثر طرق التحكم استعمالاً في الصناعة، ولشهرتها فقد تعددت وبشكل كبير الطرق المقترحة لضبطها. غرض هذه الورقة العلمية تقديم ملخص تفصيلي لسبع طرق مختلفة ومقارنة أدائها. تشمل المقارنة بعضاً من الطرق التي اقترحت في مراحل سابقة مثل: طرق زقلر-نيكولز، وأقل الخطأ، وهوامش الكسب والطور، وتوطين الأقطاب، والمنظم الخطي التربيعي. كما تضمن ذلك استخدام طرق حديثة كمنطق الغموض والطرق الجينية ودراسة أدائها. ولقد قوّمت هذه الطرق السبعة المختلفة بناء على أدائها ودرجة تعقيدها ومرونتها.

Journal of Engineering and Computer Sciences, Qassim University, PP 43-55, Vol. 1, No. 1 (January 2008/Muharram 1429H.)

Experimental Evaluation of Packed Bed Heat Transfer Relations

A. Khalil[*], M. A. Kassem[**] and M. Salama[***]
[*]*Mechanical Eng. Dept., Faculty of Engineering,*
Cairo University, Giza, Egypt, adelkhk@yahoo.com
[**]*Mechanical Eng. Dept., College of Engineering,*
Qassim University, Qassim, Saudi Arabia, mah_kassem@qec.edu.sa
[***]*M.Sc. student, Faculty of Engineering,*
Cairo University, Giza, Egypt, mohamedsalama98@hotmail.com

(Received 27/5/2007; accepted for publication 27/11/2007)

Abstract. The objective of this research is to obtain a relationship between Nusselt and Reynolds numbers of fluid flow in packed bed containing spheres of different sizes. Also, to develop a universal relationship for the Nusselt number in a wide range of Reynolds number and compare the results with those of empty tube. The experimental work covered a range of Reynolds numbers, based on tube diameter, from 2167 to 19400 at various spherical P.V.C. porous media particle diameters from 0.003 to 0.012 m as well as without porous media (empty section). The results of this experimental work show that the Nusselt number improves by a factor of 3.8 to 6.3 times when using porous media for sphere diameters ranging from 0.012 to 0.003 m respectively as compared to the empty tube. Small size spherical porous media yield much better results than large sizes because they offer more turbulence and eddy, while higher pressure drop develops. These results improve the heat transfer coefficient.

Keywords: Packed bed, Heat transfer.

List of Symbols and Abbreviations

A Area, m^2
a Constant
b Constant
C Constant
C_p Specific heat at constant pressure, kJ/kg.K
D Inner tube diameter, m
d Sphere diameter, m
f Constant
h Convective heat transfer coefficient, $W/m^2.K$
k Thermal conductivity, W/m.K
L Length, m
Nu_D Nusselt number based on tube diameter = h.D / k
$Nu_{w.o}$ Nusselt number based on tube diameter when using empty tube
Pr Prandtl number = $\mu_f . C_p / k$
ΔP Pressure drop across the test section, Pa
Q Rate of heat transfer, Watt
Re_D Reynolds Number based on tube diameter $= \rho.\mathbf{v}.D / \mu_f$
t_{hi} Hot water inlet temperature, °C
t_{ho} Hot water outlet temperature, °C
t_m Mean surface temperature, °C
V Hot water flow rate, m^3/sec
V_t Inside volume of steel tube when filled with water, m^3
V_S Spheres volume, m^3
v Hot water velocity, m/sec

** On leave: Faculty of Engineering, Cairo University.

Greek Letters

ε Porosity of the bed
ρ Density, kg/ m^3
μ_f Viscosity, kg/m s

Subscripts

f Fluid
hi Hot at inlet state
ho Hot at exit state
m Mean for the fluid
s Surface, Solid
t Tube

1. Introduction

Porous media are utilized in a wide range of engineering applications such as chemical catalytic reactors, compact thermal collectors, storage systems, heat pipe technology, building thermal insulation, combustion, solid matrix heat exchangers, petroleum reservoirs, geothermal operations, packed spheres ground water hydrology and the manufacturing of numerous products in chemical industry.

Jonsson and Catton [1] have studied the effect of Prandtl number of a medium on heat transfer across a horizontal layer. They found that the heat transfer coefficient increases with smaller particles. Nasr *et al.* [2] have studied the combination of conduction and radiation heat transfer in packed beds. They found that higher effective thermal conductivities were obtained with larger particles and higher thermal conductivity packing materials. Wu and Hwang [3] have studied experimentally and theoretically the fluid flow and heat transfer characteristics inside packed beds. They found that the heat transfer coefficient is greatly affected by Reynolds number and porosity. Elkady [4] has experimentally simulated the forced convection heat transfer from a circular pipe filled with porous media. He found that the average Nusselt number increases with increasing particle to pipe diameter ratio and Reynolds number. Afify and Berbish [5] have studied non-Darcian forced convection heat transfer and pressure drop in a circular tube filled with a packed bed. They found that the local Nusselt number is increased with decreasing the sphere diameter at constant Reynolds number. Poulikakos and Renken [6] have studied the forced convection in a channel filled with a fluid saturated porous medium. They found that increasing the sphere diameter to channel half width ratio yields an overall increase in fluid velocity and heat transfer from the fluid to wall. Vafai and Kim [7] have studied the fully developed forced convection in a porous channel bounded by parallel plates. They found that the variation of the Nusselt number for fully developed temperature and velocity fields is a function of the Darcy number only. Vafai and Sozen [8] have studied the forced convective flow of a gas through a packed bed. They found that the local thermal equilibrium assumption should not be carried out for high (Re) and/or high (Da) flows in a packed bed. Vafai and Kim [9] have studied the convective flow and heat transfer through a composite porous consists of a fluid layer overlaying a porous substrate. They found that the Darcy number is directly related to the permeability of the porous medium. Breton, Caltagirone and Arquis [10] have studied natural convection in a square cavity in which differentially heated vertical walls are covered with thin porous layers. They found that the reduction of overall Nusselt number increases with Rayleigh number. Haji [11] has studied the fully developed heat transfer to a fluid flow in a rectangular passages filled with porous materials.

2. Experimental Apparatus and Measuring Instruments

A schematic diagram of the experimental set up is shown in Fig. 1. The main parts of the experimental apparatus are test section, hot water system, cooling water system, and measuring instruments.

2.1. Test section

The test section contains four parts: test tube, outer tube, entrance and exit tubes.

2.1.1. Test tube

The test tube, which is made of steel contains the porous media and allows hot water to flow through it. It has 0.0425 m inner diameter, 0.048 m outer diameter and 0.5 m length. The thermocouples are distributed on four sections along the test tube surface, as shown in Fig. 2. The distance between each section is equal to 0.1 m. The temperature of each section is measured by means of three thermocouples distributed through the section. The 1^{st} one at the top point of the section, the second one is 90 degree from the first while the 3^{rd} one located at the bottom point in the section.

2.1.2. Outer tube

The outer tube is made from P.V.C. tube, which allows the cold water to pass through the jacket between the test tube and the outer tube, in order to achieve the isothermal surface through the test section.

No.	Title
1	Overhead tank
2	Electric heater
3	Control valve
4	Entrance tube
5	Test section
6	Exit tube
7	Lower tank
8	Lift pump
9	U- Tube manometer
10	Thermocouple
11	Hose

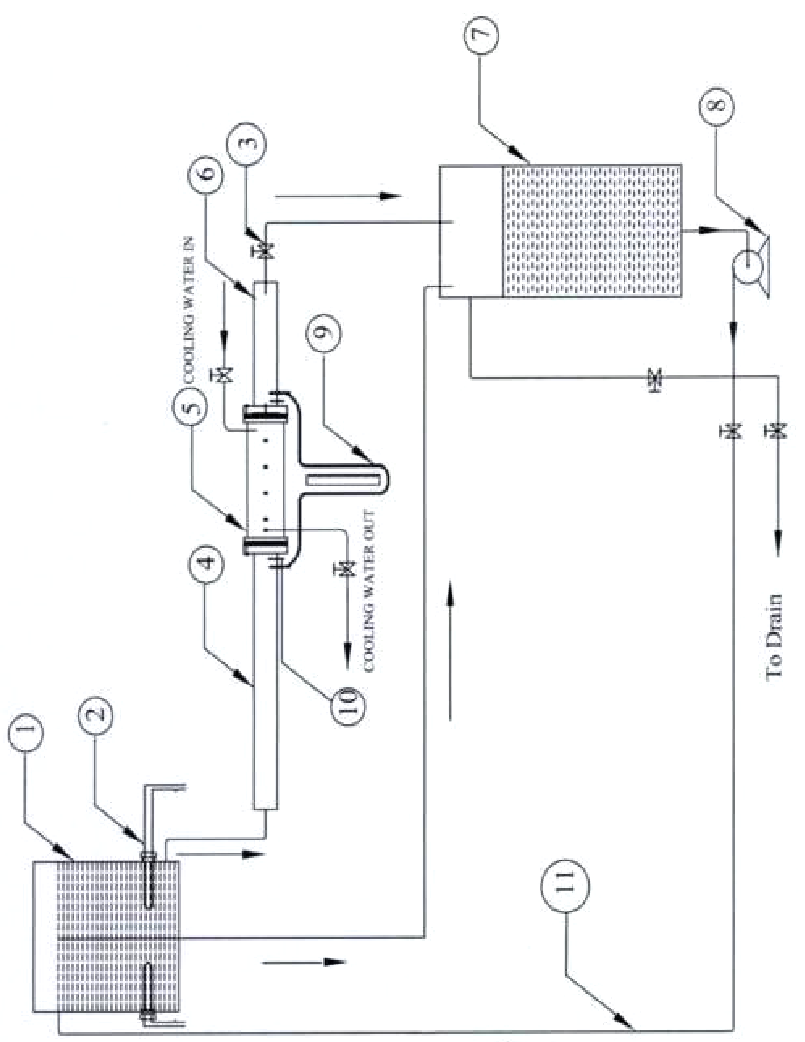

Fig. (1). Schematic diagram of the experimental set up.

2.1.3. Entrance and exit tubes

The design of the entrance tube is made to guarantee fully developed flow and almost uniform velocity at the inlet of the test section. The upstream and downstream parts of the steel tube are made from P.V.C. tube and allow thermocouples to measure the water temperatures before and after the test section.

The entrance length for the test section is designed to obtain almost uniform velocity upstream of the test section, which requires a length around 20 times the diameter as presented in [12, 13]. Therefore, the P.V.C. tube upstream the test section is selected with 1 m length, 0.0425 m inner diameter and 0.048 m outer diameter. The exit P.V.C. tube has an inner diameter of 0.0425 m, an outer diameter of 0.048 m and a length of 0.5 m. The pressure drop across the test section was measured by U-tube manometer connected upstream and downstream of the test section by using two copper taps.

2.2. Hot water system

The hot water system consists of an overhead tank, a lower collecting tank, water pump, valves and hoses. The overhead tank is used to obtain a constant water head of the hot water flow. To ensure the steadiness of the flow, the head in the tank is kept constant by means of an adjustable overflow pipe. The water is heated by two electric heaters (2 kW each) which are submerged in the overhead tank. The lower tank is used to collect the water for recycling. A water pump is used to lift the water from the lower tank to the overhead tank. Valves are used to control the hot water flow rate and to purge the air from the test rig.

2.3. Cooling water system

The open loop cold water system is obtained by cold water supply, and controlled by adjusting the control valve.

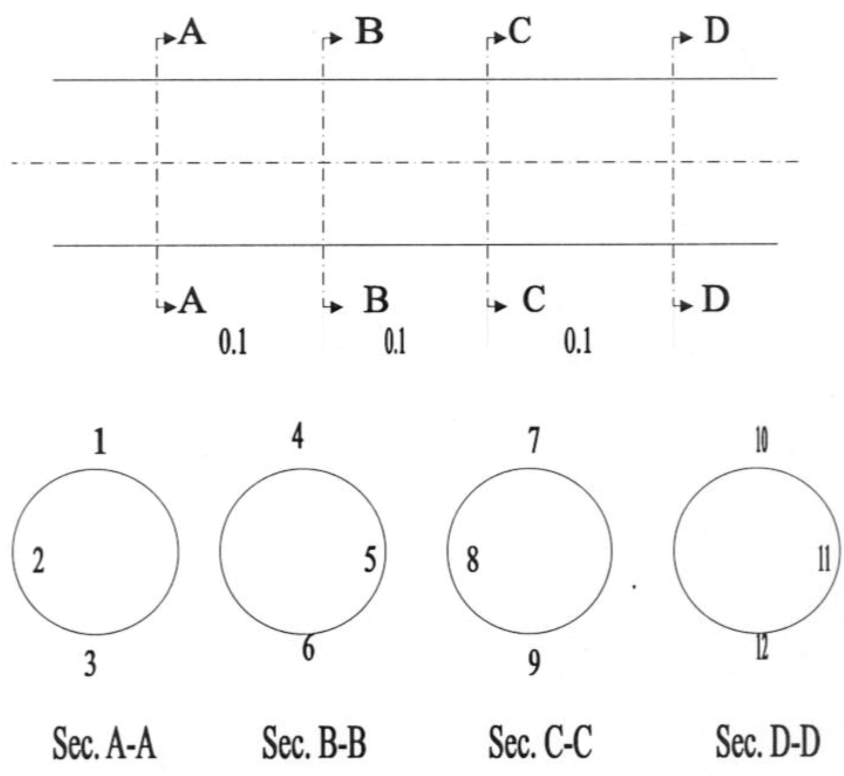

Fig. (2). Thermocouples distribution along the test section.

2.4. Measuring instruments

Measuring instruments are used to measure the physical quantities required to calculate the heat transfer coefficient. The measuring instruments are: thermocouples, a U-tube manometer, digital thermometers, a digital stop watch and a graduated vessel.

2.5. Porous media

The porous media used for the runs is P.V.C. spheres with diameters (0.003, 0.004, 0.005, 0.006, 0.008 and 0.012 m). Void fraction during this work is measured experimentally. The following equations are used to evaluate the void fraction.

$$\varepsilon = \left(\frac{V_t - V_S}{V_t} \right) \tag{1}$$

The relationship between packed bed diameter ratio and void fraction is represented in Table 1.

Table (1). Relationship between packed bed diameter ratio and void fraction.

d *10^3 m	D/d	V_t *10^6 m^3	$(V_t - V_S)$*10^6 m^3	ε
3	14.17	709.31	280	0.386
4	10.63	709.31	289	0.396
5	8.50	709.31	294	0.403
6	7.08	709.31	298	0.408
8	5.31	709.31	302	0.414
12	3.54	709.31	308	0.421

3. Method of Calculation

Main assumptions for calculations are:

- The value of Re_D is calculated based on the velocity across porous media and calculated by the following procedures:

$$\varepsilon = (V_t - V_S) / V_t = V_f / V_t \tag{2}$$

$$\varepsilon = V_f / V_t = A_f L_f / A_t L_t \tag{3}$$

If $L_f = L_t$ and $A_f / A_t = (D_f / D)^2$, then:

$$\varepsilon = A_f / A_t \tag{4}$$

$$v_f . A_f = v_t . A_t \tag{5}$$

$$v_f = v_t (A_t / A_f) \tag{6}$$

$$v_f = v_t / \varepsilon \quad \text{(velocity across porous media)} \tag{7}$$

$$Re = (\rho_f v_t D_t)/\mu_f \quad \text{(Entrance tube)} \tag{8}$$

$$Re_D = (\rho_f v_f D_f)/\mu_f \quad \text{(across porous media)} \tag{9}$$

$$Re_D / Re = v_f D_f / v_t D_t = 1/(\varepsilon)^{0.5} \tag{10}$$

$$Re_D = Re /(\varepsilon)^{0.5} \tag{11}$$

The following procedure is followed to calculate Nusselt number:

$$Q = \rho_f V c_p (t_{hi}-t_{ho}) \quad \text{Watt} \tag{12}$$

$$h = \frac{Q}{(\pi DL(t_m - t_S))} \quad \text{W/m}^2\text{.K} \tag{13}$$

where:

$$t_s = \frac{t_1 + 2*t_2 + t_3 + t_4 + 2*t_5 + t_6 + t_7 + 2*t_8 + t_9 + t_{10} + 2*t_{11} + t_{12}}{16}$$

$$t_m = \frac{t_{hi} + t_{ho}}{2}$$

$$Nu_D = h\, D/ k_f \tag{14}$$

4. Results and Discussions

The experimental work covers a wide range of Reynolds number starting from 2167 to 19400, and various spherical P.V.C. porous media diameters from 0.003 to 0.012 m. Also, experimental work covers the empty tube. Uncertainty in the measured Nusselt number is estimated as 3.9%, while it is 1.7 % in Reynolds number.

4.1. Effect of diameter ratio on heat transfer

Figures 3 and 4 show the relationship between the heat transfer coefficient, Nusselt number and Reynolds number with and without using porous media.

The effect of diameter ratio is shown. The large diameter ratio is the best case compared with the low diameter ratio because the large diameter ratio has low porosity compared with the small diameter ratio. Therefore, more turbulence occurs generating more eddies resulting in improving the Nusselt number.

The experimental work was carried out to show the effects of porous media, the results reveal that the heat transfer coefficient without using porous media is lower than that with porous media due to less turbulence, less eddies and approximately zero pressure drop on the test section.

Figure 5 shows the relationship between the Nusselt number and the diameter ratio for various values of Reynolds number. Note that the Nusselt number increases with increasing the diameter ratio. Also, the slopes of the curves are increased with increasing the Reynolds number.

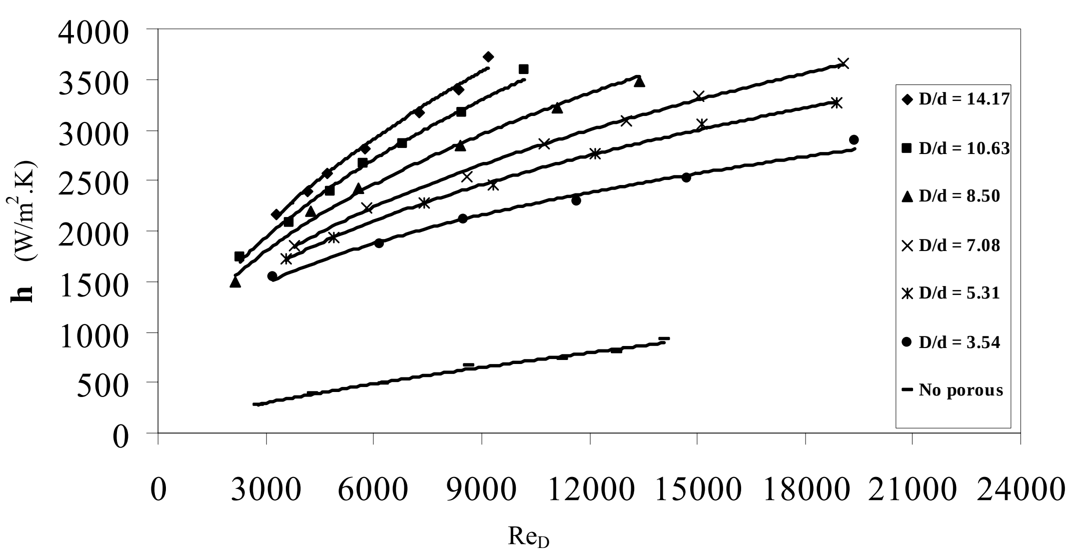

Fig. (3). Variation of heat transfer coefficients with Renolds numbers with and without porous media at the same conditions.

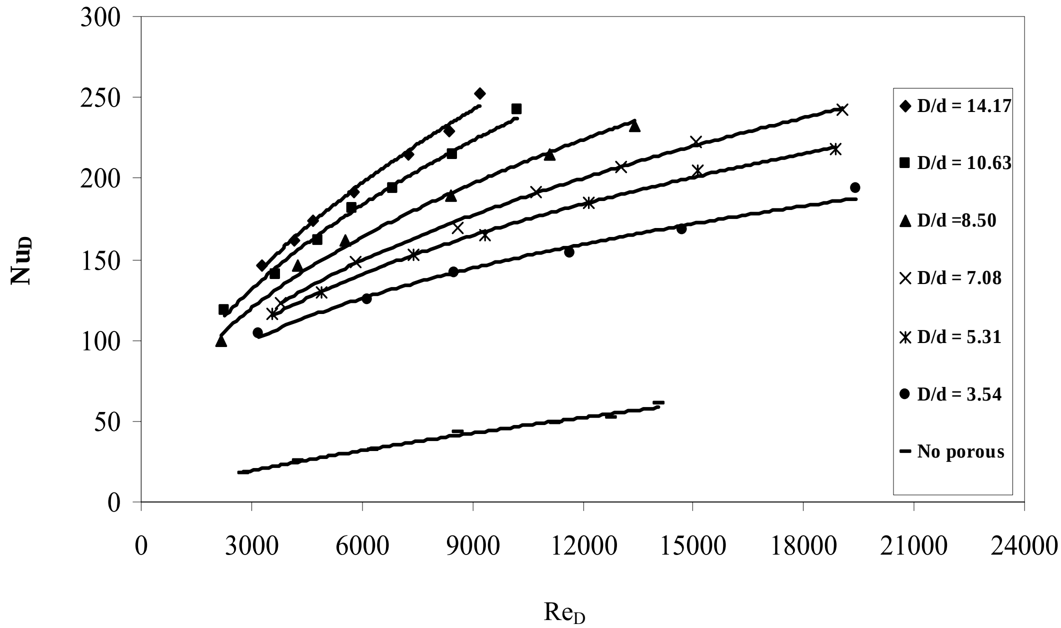

Fig. (4). Variation of Nusselt numbers with Reynolds numbers with and without porous media at the same conditions.

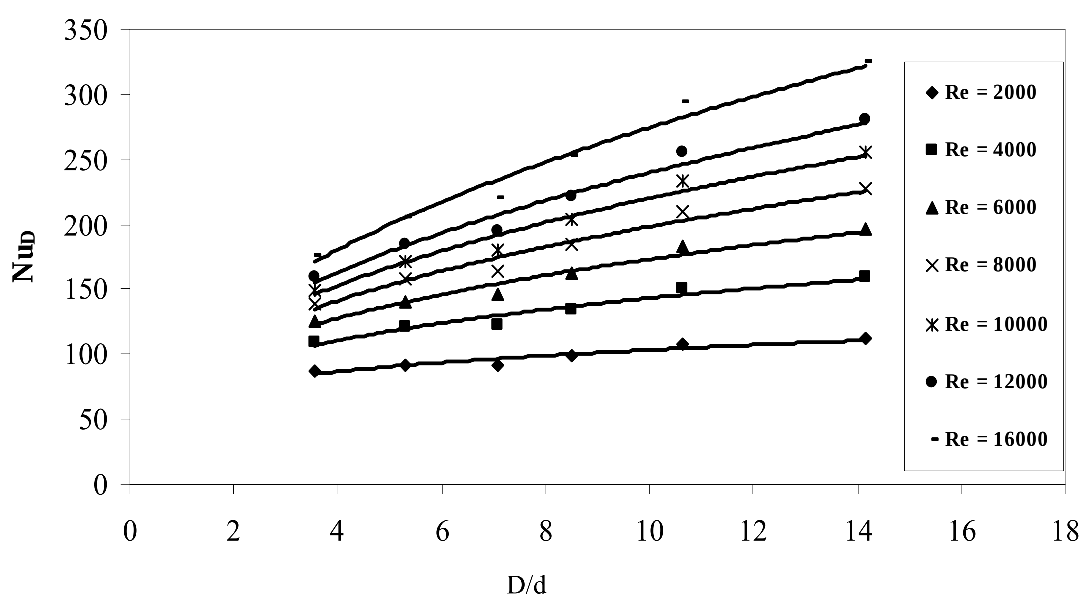

Fig. (5). Variation of Nusselt numbers with Diameter ratio for P.V.C. spheres for different Reynolds numbers at the same conditions.

4.2. Correlations of heat transfer results

The correlation between the Nusselt number and the Reynolds number at various porous sphere diameters is shown in Fig. 4, and can be addressed in the following general form:

$$Nu_D = a_1 \mathrm{Re}_D^{\,b_1} \tag{15}$$

Referring to these results, the values of the coefficients (a_1) and (b_1) are a function of diameter ratio.

$$a_1 = c_1 \left(\frac{D}{d}\right)^{f_1} \text{ and } b_1 = c_2 \left(\frac{D}{d}\right)^{f_2}$$

The final relationship becomes:

$$Nu_D = 17.30 \left(\frac{D}{d}\right)^{-0.77} \mathrm{Re}_D^{\,0.235\left(\frac{D}{d}\right)^{0.3}} \tag{16}$$

For: $2167 \le \mathrm{Re}_D \le 19400$ and
$3.54 \le D/d \le 14.16$.

This relation gives error in the range ± 7%. The relationship is correlated as shown in Fig. 6. For empty tube the relationship between the Nusselt number and Reynolds number without using porous media is:

$$Nu_D = 0.042 \ \mathrm{Re}_D^{\,0.76} \tag{17}$$

For: $2778 \le \mathrm{Re}_D \le 14000$ and
$1.5 \le \mathrm{Pr} \le 3.4$

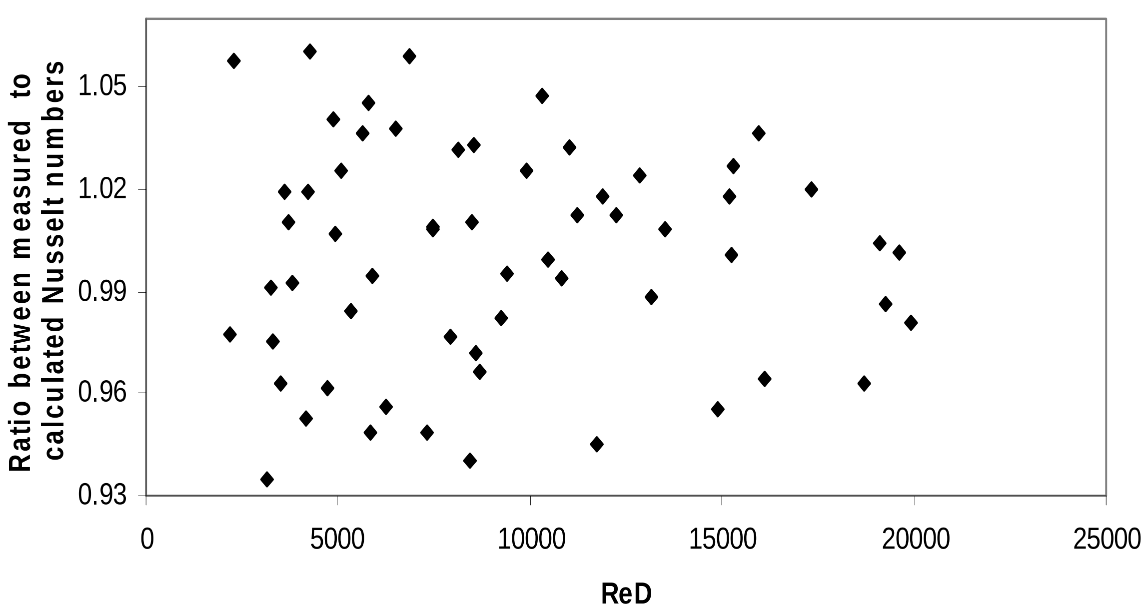

Fig. (6). Variation of the ratio of measured to calculated Nusselt numbers with Reynolds numbers.

4.3. Effect of packed bed on heat transfer enhancement

The results of this experimental work, which is shown by Eqs. (16) and (17) prove that the Nusselt number and heat transfer coefficient are improved due to the use of porous media as shown in Table 2.

The results of this experimental work show that the Nusselt number improves by a factor of 3.8 to 6.3 times when using porous media for porous diameters from 0.012 to 0.003 m respectively as compared to the empty tube.

Table (2). Ratio between packed bed Nusselt number and empty tube Nusselt number for different porous media diameters.

d *10^3 m	$Nu_D/Nu_{W.O}$ Re_D 3000	$Nu_D/Nu_{W.O}$ Re_D 6000	$Nu_D/Nu_{W.O}$ Re_D 9000	$Nu_D/Nu_{W.O}$ Re_D 12000	$Nu_D/Nu_{W.O}$ Re_D 15000	$\left(\frac{Nu_D}{Nu_{W.O}}\right)_{av}$
3	7.8	6.6	6.0	5.6	5.3	6.3
4	6.9	5.7	5.1	4.7	4.4	5.4
5	6.4	5.2	4.6	4.2	3.9	4.9
6	6.1	4.8	4.2	3.8	3.5	4.5
8	5.8	4.5	3.8	3.5	3.2	4.1
12	5.5	4.1	3.5	3.1	2.8	3.8

4.4. Effect of diameter ratio on pressure drop

Figure 7 shows the relationship between pressure drop across the test section and Reynolds number for various sphere diameters. This figure shows that the slope of pressure drop increases upon decreasing the sphere diameter. This result is expected because of using small spheres porous media generates high pressure drop due to more turbulence that results in high heat transfer coefficient as compared to large spheres porous media.

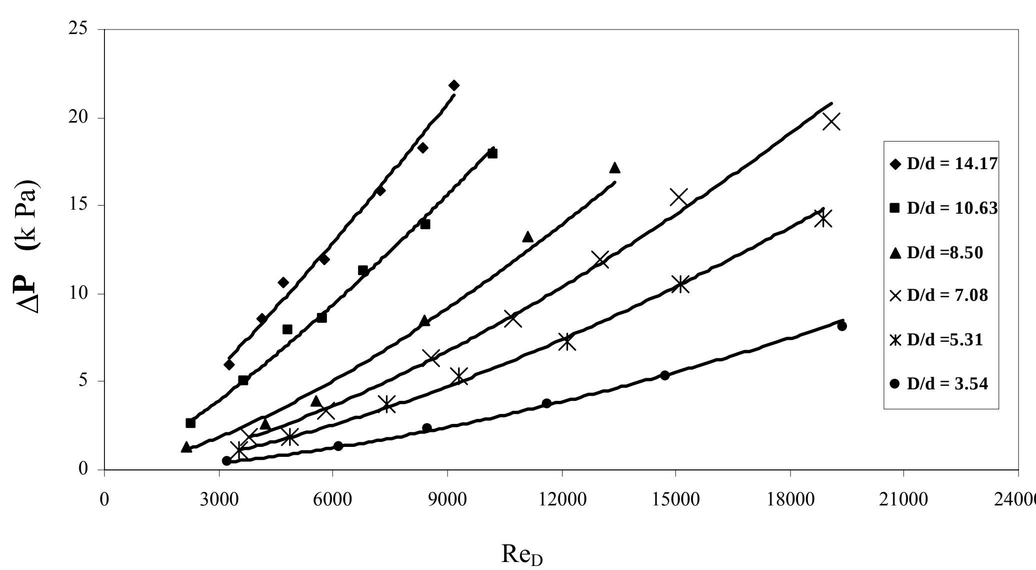

Fig. (7). Variation of pressure drop with Reynolds numbers for P.V.C. spheres of different diameters at the same conditions.

4.5. Correlations of the pressure drop results

By the same way the correlation between the dimensionless pressure drop and Reynolds number at various sphere diameters can be expressed in the following general form:

$$\frac{\Delta P}{\frac{1}{2}\rho V^2} = a_2 \operatorname{Re}_D{}^{b_2} \tag{18}$$

The values of the coefficients (a_2) and (b_2) are functions of the diameter ratio. The following relationships are obtained:

$$a_2 = c_3 e^{f_3 (D/d)}$$

$b_2 = f_4 (d / D) + f_5$

The final relationship becomes:

$$\frac{\Delta P}{\frac{1}{2}\rho V^2} = (1\times 10^{-4} e^{0.62(D/d)}) \operatorname{Re}_D{}^{(-0.045(D/d)+1.8)} \tag{19}$$

where: $2167 \le \operatorname{Re}_D \le 19400$ and $3.54 \le D/d \le 14.16$.

This relation gives errors in the range of $\pm 9.5\%$ error.

4.6. Comparison between the present and previous work

When using packed tube the equation 16 is obtained. Elkady [4] reported the correlation between Nu_D and Re_D as follows:

$$Nu_D = 0.023(k_S/k_f)^{0.48}(D/d)^{0.66} \operatorname{Re}_D{}^{0.8} \Pr{}^{0.4} \tag{20}$$

where: $4141 \le \operatorname{Re}_D \le 14550$, $1.28 \le D/d \le 1.85$ and $6.54 \le k_S/k_f \le 2160$.

The present results shown in Eq. (16) are compared with Eq. (20) as shown in Fig. 8. The deviation between the present work and Elkady [4] at $Re_D = 6000$ is equal to - 8% but at $Re_D = 10000$ the deviation is equal to +14% due to different design parameters and experimental states.

The following table shows the difference between the present work and Elkady [4].

Table (3). The deviation between the present and Elkady [4] parameters.

Parameter	Present work	Elkady [4]
Test section	Steel tube	Copper tube
Test tube size	Di= 0.0425m, Do= 0.048 m and L=0.5 m	Di= 0.0204m, Do= 0.0225 m and L=0.7 m
D/d	3.54 - 14.16	1.28 - 1.85
kS/kf	0.24	6.54 – 2160
Porous media	P.V.C	Glass - Steel - P.V.C
Classification of work	Experimental	Experimental
Working Fluid	Water	Air
Porosity	0.38-0.42	0.53-0.6
ReD	2167-19400	4000-14000

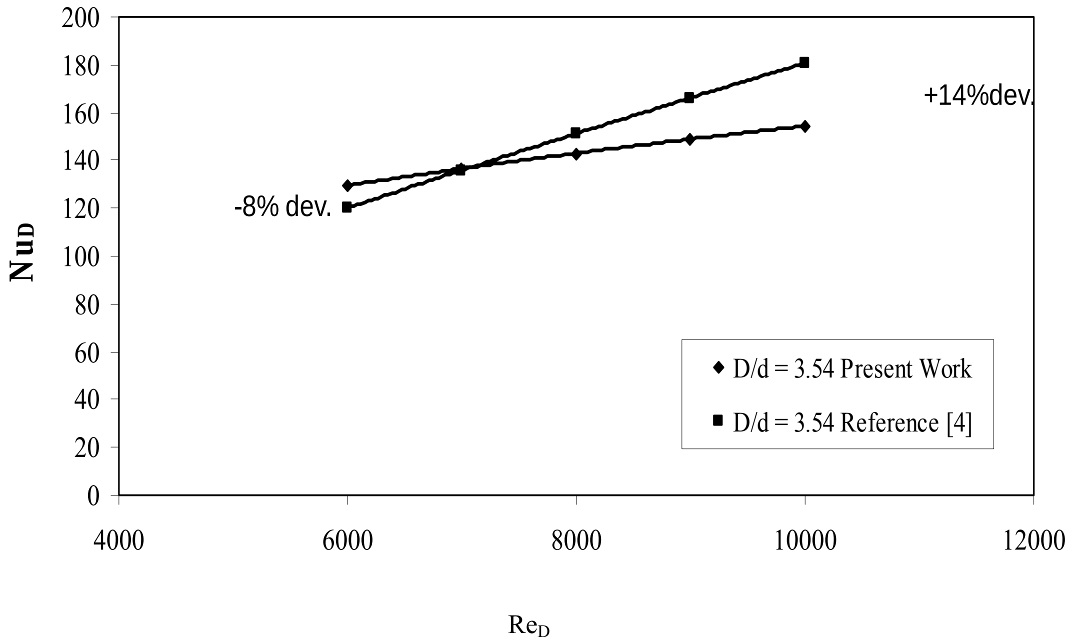

Fig. (8). Comparison between experimental work and Ref. [4] for packed bed tube.

5. Conclusions

The main conclusions from the present work are:

1. The heat transfer coefficient is improved by increasing Reynolds number (due to increasing the flow rate), resulting in an increase in Nusselt number.
2. The general correlation between Nusselt number and Reynolds number using porous material is presented by Eq. (16) for various diameter ratios and it has ± 7% error.
3. The general correlation between Nusselt number and Reynolds number without porous material is shown in Eq. (17).
4. Utilizing small sphere diameters are much better than using large diameters because they offer more turbulence and eddies which result in improving the heat transfer coefficient. On the other hand, higher pressure drop develops.
5. The results reveal that the heat transfer coefficient without using porous media is lower than the heat transfer coefficient when using porous media due to less turbulence, less eddies and approximately zero pressure drop on the test section.
6. The Nusselt number improves a factor of 3.8 to 6.3 times when using porous media for porous diameters from 0.012 to 0.003 m respectively as compared to the empty tube.
7. The general relationship between dimensionless pressure drop and Reynolds number at various sphere diameters is shown in Eq. (19) and it has a maximum error of ± 9.5%.

6. References

[1] Jonsson, T. and Catton, I. "Prandtl Number Dependence of Natural Convection in Porous Media." *Journal of Heat Transfer,* 109 (May 1987), 371-377.

[2] Nasr, K.; Viskanta, R. and Ramadhyani, S. "An Experimental Evaluation of the Effective Thermal Conductivities of Packed Beds at High Temperatures." *Journal of Heat Transfer,* 116 (November 1994).

[3] Wu, C.C. and Hwang, J.G. "Flow and Heat Transfer Characteristics Inside Packed and Fluidized Beds." *Journal of Heat Transfer,* 120 (August 1998), 667-673.

[4] Elkady, S.M. "Enhancement of Forced Convection Heat Transfer from a Cylindrical Pipe Using Porous Media of High Diameter Ratios." *11th International Mechanical Power Engineering Conference,* Cairo, (February 5-7, 2000).

[5] Afify, R. and Berbish, N. "Experimental Study of Non-Darcian Forced Convection Heat Transfer in Packed Circular Tube." *11th International Mechanical Power Engineering Conference,* Cairo, (February 5-7, 2000).

[6] Poulikakos, D. and Renken, K. "Forced Convection in a Channel Filled with Porous Medium, Including the Effects of Flow Inertia, Variable Porosity, and Brinkman Friction." *Journal of Heat Transfer,* 109 (November 1987).

[7] Vafai, K. and Kim, J.S. "Forced Convection in a Channel Filled with a Porous Medium: An Exact Solution." *Journal of Heat Transfer,* 111 (November 1989), 1103-1106.

[8] Vafai, K. and Sozen, M. "Analysis of Energy and Momentum Transport for Fluid Flow Through a Porous Bed." *Journal of Heat Transfer,* 112 (August 1990), 690-6999.

[9] Vafai, K. and Kim, J.S. "Analysis of Surface Enhancement by a Porous Substrate." *Journal of Heat Transfer,* 112 (August 1990), 700-706.

[10] Le Breton, P.; Caltagirone, P.J. and Arquis, E. "Natural Convection in a Square Cavity with Thin Porous Layers on Its Vertical Walls." *Journal of Heat Transfer,* 113 (November 1991), 892-898.

[11] Haji-Shaekh, A. "Fully Developed Heat Transfer and Fluid Flow in Rectangular Passage Filled with Porous Materials." *Journal of Heat Transfer,* 128 (June 2006), 550-556.

[12] Incropera, F. and De Witt. D.P. *Fundamentals of Heat and Mass Transfer.* 3rd ed., New York: John Wiley & Sons, 1996.

[13] Salama, M. "Experimental Evaluation of Packed Bed Heat Transfer Relations." *M.Sc. Thesis, Faculty of Engineering, Cairo University,* Cairo, (April 2004).

تقدير معملي لعلاقات انتقال الحرارة بالأوساط المسامية

عادل خليل*، محمود عبد الوهاب قاسم، محمد سلامة*****

* قسم الهندسة الميكانيكية، كلية الهندسة-جامعة القاهرة، الجيزة- مصر

** قسم الهندسة الميكانيكية، كلية الهندسة-جامعة القصيم، القصيم- السعودية

*** طالب ماجستير - قسم الهندسة الميكانيكية، كلية الهندسة-جامعة القاهرة، الجيزة-مصر

(قُدم للنشر في ٢٠٠٧/٥/٢٧م ؛ وقُبل للنشر في ٢٠٠٧/١١/٢٧م)

ملخص البحث. يهدف البحث إلى إيجاد العلاقة بين معامل انتقال الحرارة وسرعة سريان المائع في الأوساط المسامية. والوسط المسامي المستخدم هو وسط يتكون من كريات من مادة البولي فينيل كلوريد بأقطار مختلفة (من ٠٫٠٠٣ إلى ٠٫٠١٢ م). وقد تم وضع العلاقات في صورة لا بعدية على صورة علاقة بين رقم نوسلت ورقم رينولدز. والنسبة بين قطر أنبوب السريان إلى قطر كريات المادة المسامية. كذلك تم اختبار أنبوب فارغ بهدف مقارنة معامل انتقال الحرارة والفقد في الضغط خلال الأوساط المسامية والأوساط غير المسامية.

وقد خلصت الدراسة إلى النتائج التالية :

١- العلاقة بين رقم نوسلت ورقم رينولدز والنسبة بين قطر أنبوب السريان الى قطر الكريات كانت كالتالي :

$$Nu_D = 17.30\left(\frac{D}{d}\right)^{-0.77} \mathrm{Re}_D^{\,0.235\left(\frac{D}{d}\right)^{0.3}}$$

٢- العلاقة بين الفقد في الضغط ورقم رينولدز والنسبة بين قطر أنبوب السريان إلى قطر الكريات كالتالي :

$$\frac{\Delta P}{\frac{1}{2}\rho V^2} = \left(1\times 10^{-4} e^{0.62\,(D/d)}\right) \mathrm{Re}_D^{\,(-0.045\,(D/d)+1.8)}$$

٣- أدى استخدام أوساط مسامية إلى زيادة معامل انتقال الحرارة بنسبة تتراوح من ٣٫٨ إلى ٦٫٣ اعتمادًا على النسبة بين قطر أنبوب السريان وقطر الكريات عند تساوي رقم رينولدز .

Journal of Engineering and Computer Sciences, Qassim University, PP 1-18, Vol. 1, No. 1 (January 2008/Muharram 1429H.)

The Modern Syllogistic Method as a Tool for Engineering Problem Solving

Ali M. Rushdi[*] and Omar M. Ba-Rukab[**]

[*]*Electrical and Computer Eng. Dept., King Abdulaziz University, P.O. Box 80204, Jeddah 21589, Saudi Arabia, arushdi@kau.edu.sa*

[**]*College of Telecom. and Electronics, P.O. Box 2816, Jeddah 21461, Saudi Arabia, obarukab@yahoo.com*

(Received 20/6/2007; accepted for publication 6/11/2007)

Abstract. We describe the steps and the main features of the modern syllogistic method, which is a very powerful technique of deductive inference. This method ferrets out from a set of premises all that can be concluded from it, with the resulting conclusions cast in the simplest or most compact form. We demonstrate the applicability of the method in a variety of engineering problems via five examples that illustrate its mathematical details and exhibit the nature of conclusions it can come up with. The method is shown to be particularly useful for detecting inconsistency within a set of given premises or hypotheses and it helps the engineer confront fallacy-based argumentation. The method is also demonstrated to yield fruitful results when combined with the safety technique known as fault-tree analysis. It is also used in selective deduction and in informed decision making.

Keywords: Deductive inference, Modern syllogistic method, Detecting inconsistencies, Real and perceived problems, Selective deduction, Informed decision making.

1. Introduction

One of the important traits of a successful engineer is logical thinking [1]. This trait can usually be acquired and mastered through appropriate training in deductive and inductive logic [2, 3]. Such training does not necessarily guarantee that a person can reason well or correctly, but a person knowledgeable about logic techniques is more likely to reason correctly than one who is unaware of them. In the past, smart individuals realized that they could think logically without the resort to the deductive logic techniques that were available to them, while dummy individuals failed to derive any benefit from these techniques, which were complex and cumbersome indeed. Traditional logicians applied deductive logic to contextual reasoning, and were deeply concerned with verbal fallacies. In its modern formal outlook, logic is a science of correct forms in which the study of such fallacies is irrelevant, and it has two distinctive branches of deduction and induction that are both essential as they play complementary rather than competitive roles in inference [3].

In this paper, we describe the steps, features and some applications to engineering problem solving of a very powerful technique for deductive inference, which we call "the modern syllogistic method". The first popular description of this method is given by Brown [4]. Later presentations of the method are given by Gregg [5] and Rushdi and Al-Shehri [6]. The great advantage of the method is that it ferrets out from a given set of premises all that can be concluded from this set, and it casts these conclusions in the simplest or most compact form.

The remainder of this paper is organized as follows. Section 2 outlines the steps of the modern syllogistic method, while Section 3 lists its main features. Section 4 illustrates some applications of the method to engineering problem solving in terms of five examples. Example 1 presents typical deductions by the method in the context of a problem of mechanism testing or troubleshooting. Examples 2 and 3 demonstrate how the method can test hypotheses or detect inconsistencies within a set of premises. This feature is very useful for the engineer in his role as a problem solver because he can avoid falling into the trap of solving a perceived problem, which is a problem thought to be correctly defined while, in fact, it is not. The same feature is also necessary for the engineer in his role as an argumenter, because it assists him to avoid being deceived by those who use inconsistent premises to validly deduce false conclusions, no matter how irrelevant they are. Example 4 combines the method with the well known safety technique of fault-tree analysis, thereby producing substantially fruitful results. The ramifications of such a combination are far reaching and warrant further exploration. Example 5 presents a case of selective deduction and informed decision making. Section 5 concludes the paper.

2. Steps of the Modern Syllogistic Method

The modern syllogistic method has the following steps:

1. Each of the premises is converted into the form of a formula equated to 0 (which we call an equational form), and then the resulting equational forms are combined together into a single equation of the form $f = 0$. If we have n logical equivalence relations of the form:

$$T_i \equiv Q_i \,, \qquad 1 \le i \le n \,, \tag{1}$$

Then they are set in the equational form:

$$T_i \, \overline{Q}_i \vee \overline{T}_i \, Q_i = 0 \,, \qquad 1 \le i \le n. \tag{2}$$

We may also have ($m - n$) logical implication (logical inclusion) relations of the form:

$$T_i \rightarrow Q_i \,, \qquad (n+1) \le \mathrm{i} \le m \,. \tag{3}$$

These relations symbolize the statements " $If\ T_i\ then\ Q_i$ " or equivalently " $T_i\ if\ only\ Q_i$ ". The conditions in (3) can be set into the equational form:

$$T_i \, \overline{Q}_i = 0, \qquad (n+1) \le \mathrm{i} \le m. \tag{4}$$

The totality of m premises in Eqs. (1) and (3) finally reduce to the single equation $f = 0$, where f is given by [7]:

$$f = \bigvee_{i=1}^{n} (T_i \, \overline{Q}_\mathrm{i} \vee \overline{T}_i \, Q_i) \ \vee \bigvee_{i=(n+1)}^{m} T_i \, \overline{Q}_i. \tag{5}$$

Equations (1) and (3) represent the dominant forms that premises can take. Other less important forms are discussed by Klir and Marin [8] and can be added to Eq. (5) when necessary.

2. The function f in Eq. (5) is rewritten as a complete sum (Blake canonical form), i.e. as a disjunction of all the prime implicants of f . There are many manual and computer algorithms for developing the complete sum of a switching function f [4, 9-11]. Most of these algorithms depend on two logical operations: (a) Consensus generation (or equivalently multiplying a product of sums into a sum of products), and (b) absorption.
3. Suppose the complete sum of f takes the form:

$$f = \bigvee_{i=1}^{\ell} P_i = 0 , \tag{6}$$

where P_i is the i th prime implicant of f . Equation (6) is equivalent to the set of equations:

$$P_i = 0 , \qquad 1 \le i \le \ell. \tag{7}$$

Equation (7) states in the simplest equational form all that can be concluded from the original premises. The conclusions in Eq. (7) can also be cast into the implication form. Suppose P_i is given as a conjunction of uncomplemented literals X_{ij} and complemented literals; $\overline{Y}_{ij}$, i.e.

$$P_i = \bigwedge_{j=1}^{r} X_{ij} \wedge \bigwedge_{j=1}^{s} \overline{Y}_{ij} , \qquad 1 \le i \le \ell , \tag{8}$$

then, Eq. (7) can be rewritten as:

$$\bigwedge_{j=1}^{r} X_{ij} \rightarrow \overline{(\bigwedge_{j=1}^{s} \overline{Y}_{ij})}, \quad 1 \le i \le \ell , \tag{9}$$

or as:

$$\bigwedge_{j=1}^{r} X_{ij} \rightarrow \bigvee_{j=1}^{s} Y_{ij} , \quad 1 \le i \le \ell . \tag{10}$$

3. Important Features of the Modern Syllogistic Method

1. The modern syllogistic method produces all possible consequents (since CS(*f*) is a disjunction of all the prime implicants of *f*), and it casts these consequents in the most compact form (since all the implicants in CS(*f*) are prime ones). If any implicant (whether it is prime or not) of *f* is equated to 0, then the result is a true consequent (albeit not necessarily in the most compact form) [4].
2. To test the truth of any claimed consequent based on a given set of premises, one just needs to cast these claimed consequents in the form of a disjunction of terms equated to 0, and check to see if each of these terms subsumes (at least) one of the prime implicants in CS(*f*) derived for the set of premises.
3. The modern syllogistic method encompasses a complete set of inference rules, and constitutes a complete system of truth-functional logic, in the sense that it permits the construction of a formal proof of validity for any valid truth-functional argument [6].
4. The modern syllogistic method has a built-in capability of detecting the existence of inconsistency within a given set of premises, The method will alert its user to the existence of concealed inconsistencies by producing CS(*f*)=1. Once this happens, the user should refrain from making any conclusion, and should revise his set of premises to change it into a consistent one.
5. The modern syllogistic method can be used in detecting and invalidating certain purported arguments or formal fallacies, such as the converse fallacy (the fallacy of affirming the consequent) or the inverse fallacy (the fallacy of denying the antecedent).
6. The modern syllogistic method is very useful in the case of selective deduction [12], which is deduction with the knowledge of certain information or restrictions, or the lack thereof, about some of the pertinent variables. The method handles selective deduction by:

a) either selecting the appropriate subset of the set of prime implicants in Eq. (6) or by obtaining the appropriate conjunctive eliminant [4] or meet derivative [13] of f in Eq. (5), and then casting it in complete-sum form [12], or
b) restricting the values of appropriate variables by assigning each of them one of the constant values 0 or 1.

7. As a formal technique of logic, the modern syllogistic method concerns itself only with the form of its premises and consequents and has nothing to do with their subject matter. It is up to the user of the method to use plausible heuristics to formulate the premises and interpret the consequents. The intervening task of going from the formal premises to the formal consequents is tackled in a completely algorithmic fashion by the method. By contrast, the heuristics required of the user are fallible, involve some linguistic and verbal elements, and cannot be replaced by exact recipes or algorithms.

4. Examples

4.1. Example 1

This example is posed as a problem by Brown [4]. It illustrates the mathematical details of the method and the clear insight it provides in going from intricate premises to much simplified consequents. Consider the following situation. The state of a mechanism under test is shown by five indicators, labeled A, B, C, D and E. After watching the indicators for a long time, an observer characterizes the mechanism as follows:

a) If A or D is on (but not both), then C is on.
b) Looking just at C, D and E, the number of on-indicators is always odd.
c) If E is off, then A and D are both off.
d) If B and C are both on, then E is on.
e) At least one of the following conditions always exists:
    i) A on.
    ii) C off.
    iii) D on.

Express the prime consequents in clausal form.

Conditional form	Equational form
$A \oplus D \rightarrow C$	$A\overline{D}\,\overline{C} \vee \overline{A}D\overline{C} = 0$
$C \oplus D \oplus E$	$\overline{C}\,\overline{D}\,\overline{E} \vee CD\overline{E} \vee C\overline{D}E \vee \overline{C}DE = 0$
$\overline{E} \rightarrow \overline{A}\,\overline{D}$	$\overline{E}A \vee \overline{E}D = 0$
$BC \rightarrow E$	$BC\overline{E} = 0$
$A \vee \overline{C} \vee D$	$\overline{A}C\overline{D} = 0$

The given data are, therefore, equivalent to the propositional equation $f = 0$, where f is given by:

$$f = A\overline{D}\,\overline{C} \vee \overline{A}D\overline{C} \vee \overline{C}\,\overline{D}\,\overline{E} \vee CD\overline{E} \vee C\overline{D}E \vee \overline{C}DE \vee \overline{E}A \vee \overline{E}D \vee BC\overline{E} \vee \overline{A}C\overline{D} \tag{11}$$

The complete sum for f (the Blake canonical form for f) is obtained by the improved Tison method [11] as shown in Fig. 1 in which consensi are formed with respect to each of the four variables A, C, D and E respectively. No consensi are formed with respect to the variable B since it is a monoform variable. Each step of consensus generation is followed by a step of absorption in which a term is absorbed by another if the former subsumes the latter (i.e., if the set of literals for the absorbed term is a superset of the literals for the absorbing term). In Fig. 1, encircled terms are those absorbed, while those surviving absorption are set in bold. The formula expressing f gradually evolves as:

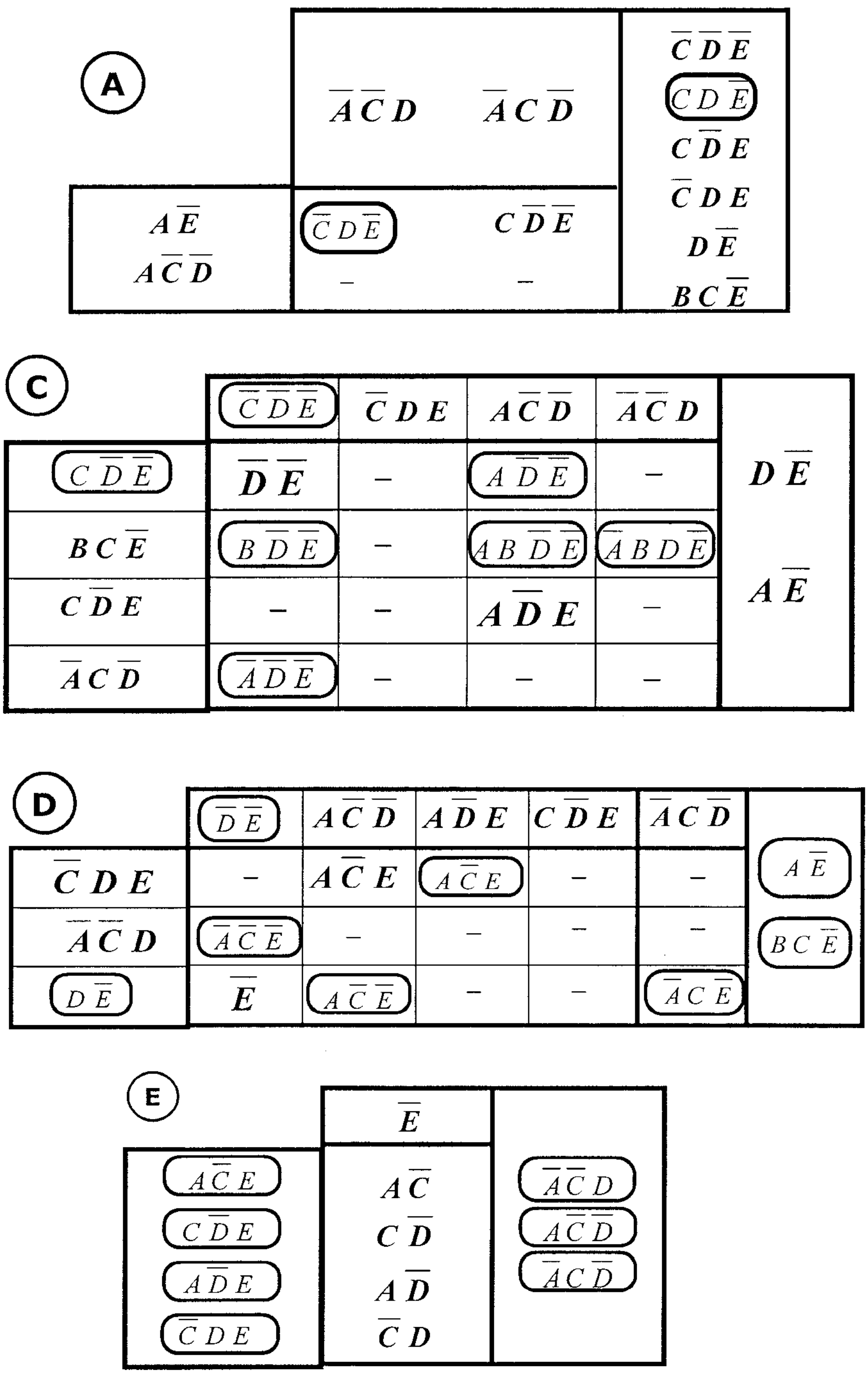

Fig. (1). Derivation of the complete sum for in Eq. (12) by the imporoved Tison method.

$$f = A\,\overline{E} \vee A\,\overline{C}\,\overline{D} \vee \overline{A}\,\overline{C}\,D \vee \overline{A}\,C\,\overline{D} \vee \overline{C}\,\overline{D}\,\overline{E} \vee C\,D\,\overline{E}$$

$$\vee C\,\overline{D}\,E \vee \overline{C}\,D\,E \vee D\,\overline{E} \vee B\,C\,\overline{E}$$

$$= C\,\overline{D}\,\overline{E} \vee B\,C\,\overline{E} \vee C\,\overline{D}\,E \vee \overline{A}\,C\,\overline{D} \vee \overline{C}\,\overline{D}\,\overline{E} \vee \overline{C}\,D\,E$$

$$\vee A\,\overline{C}\,\overline{D} \vee \overline{A}\,\overline{C}\,D \vee D\,\overline{E} \vee A\,\overline{E}$$

$$= \overline{C}\,D\,E \vee \overline{A}\,\overline{C}\,D \vee D\,\overline{E} \vee \overline{D}\,\overline{E} \vee A\,\overline{C}\,\overline{D} \vee A\,\overline{D}\,E$$

$$\vee C\,\overline{D}\,E \vee \overline{A}\,C\,\overline{D} \vee A\,\overline{E} \vee B\,C\,\overline{E}$$

$$= A\,\overline{C}\,E \vee C\,\overline{D}\,E \vee A\,\overline{D}\,E \vee \overline{C}\,D\,E \vee \overline{E}$$

$$\vee \overline{A}\,\overline{C}\,D \vee A\,\overline{C}\,\overline{D} \vee \overline{A}\,C\,\overline{D}$$

$$= \overline{E} \vee A\,\overline{C} \vee A\,\overline{D} \vee C\,\overline{D} \vee \overline{C}\,D \qquad (12)$$

where the last formula stands for $CS(f)$, i.e. it is a disjunction of all the prime implicants of f. Equation (12) is equivalent to:

$$\overline{E} = 0, \qquad (13a)$$

$$A\,\overline{C} \vee A\,\overline{D} = 0, \qquad \{A \to C\,D\} \qquad (13b)$$

$$C\,\overline{D} \vee \overline{C}\,D = 0, \qquad \{C \equiv D\} \qquad (13c)$$

We therefore conclude that indicator E is always on, and if A is on, then both C and D are on, while indicators D and C always assume the same instantaneous value, i.e. they are both on or they are both off. For indicator B, we lack any kind of information, though our premises suggest that we have something to tell about B. To verify the solution, we can ascertain that any term in the equational forms of the premises subsumes at least one prime implicant in $CS(f)$, and that if the consequents in Eq. (13) are imposed on the premises, each of the premises turns into a tautology.

4.2. Example 2

The scenario discussed in this example is a case study about differentiating a perceived problem from a real one [14]. There is a toxic discharge from a chemical plant into a nearby river. Due to a summer drought, the discharge might no longer be sufficiently dilute to be safe to aquatic life. In fact, the discharge is believed to be responsible for an unusually high number of dead fish that is turning up in the river. An engineer is called upon to design a million-dollar waste treatment facility to reduce the toxic chemical concentration by a factor of 10. However, his investigations indicate that dead fish are appearing at the same unusually high rate everywhere, not just downstream of the plant. Let us introduce the propositional variables:

T = The plant discharges toxic chemicals into the river.
D = The toxic chemicals flow downstream.
U = The toxic chemicals flow upstream.
N = Fish die downstream.
P = Fish die upstream.

We now test the hypothesis that fish die if and only if there are toxic chemicals. Our premises are:

Clausal form	Conditional form
T	$\overline{T}=0$
$T \to D$	$T\,\overline{D}=0$
$T \to \overline{U}$	$T\,U=0$
$N \equiv D$	$N\,\overline{D} \vee \overline{N}\,D=0$
$P \equiv U$	$P\,\overline{U} \vee \overline{P}\,U=0$
N	$\overline{N}=0$
P	$\overline{P}=0$

These premises combine to give the function:

$$f=\overline{T} \vee T\,\overline{D} \vee T\,U \vee N\,\overline{D} \vee \overline{N}\,D \vee P\,\overline{U} \vee \overline{P}\,U \vee \overline{N} \vee \overline{P}, \tag{14}$$

whose complete sum is:

$$CS(f)=1, \tag{15}$$

which leads to the contradiction 1=0. This means that the set of premises is inconsistent. There is no way to make all the premises true at the same time. Moreover, the given set of premises validly yields any conclusion, no matter how irrelevant [3]. In the above situation, the remedy for the inconsistency is to discard (at least) one of the given premises. The engineer must abandon the premises $N \equiv D$ and $P \equiv U$ which arise from the notion that his factory's chemicals are the real fish killer. Further investigations can lead to the real culprit which turns out to be a certain type of fungus in the given scenario [14].

We have deliberately chosen the current example to be a small one, so that the reader might easily convince himself about the existence of inconsistency among the premises by just viewing their verbal statements and without the resort to the logic technique. In more sophisticated and involved scenarios, inconsistency within a set of premises is much harder to detect and is intricately concealed and hidden. The engineer cannot usually handle such scenarios bare-handed, but he will hopefully be able to tackle them when armed with the present powerful method.

4.3. Example 3

This example does not deal with an engineering problem per se, though it handles a problem of concern to many engineers. It demonstrates how an engineer can confront illogical thinking and fallacious argumentation. Consider the situation of a retiring engineer who has served his company for two consecutive periods of time. In the first period, the terms of employment were decided by an old set of statutes (O), but in the second period the company switched to a new set of statutes (N). Each set of statutes is self consistent and strives to achieve its own sense of justice. According to the old statutes, the end-of-service gratuity is a full-month salary (F) per year of service, but this gratuity is only a half-month salary (H) per year of service in the new statutes. Also, the new statutes set an upper limit (L) on the gratuity, while in the old statutes there is no such limit. If the engineer's service is considered continuous (C), the engineer receives a total gratuity (T) for his total service according to his initial contract based on the old statutes. Otherwise, he receives two split gratuities (S), one covering his first period of service and based on the old statutes, and another fresh one covering his second period and based on the new statutes. We now formalize the aforementioned premises as follows:

Clausal form	Conditional form
$O \rightarrow F\,\overline{L}$	$O\,\overline{F} \vee O\,L = 0$
$N \rightarrow H\,L$	$N\,\overline{H} \vee N\,\overline{L} = 0$
$C \rightarrow O\,T$	$C\,\overline{O} \vee C\,\overline{T} = 0$
$\overline{C} \rightarrow N\,S$	$\overline{C}\,\overline{N} \vee \overline{C}\,\overline{S} = 0$
$N \equiv \overline{O}$	$NO \vee \overline{N}\,\overline{O} = 0$
$S \equiv \overline{T}$	$S\,T \vee \overline{S}\,\overline{T} = 0$

These premises are now combined into a single equation of the form:

$$f = O\,\overline{F} \vee O\,L \vee N\,\overline{H} \vee N\,\overline{L} \vee C\,\overline{O} \vee C\,\overline{T} \vee \overline{C}\,\overline{N} \vee \overline{C}\,\overline{S} \vee N\,O \vee \overline{N}\,\overline{O} \vee S\,T \vee \overline{S}\,\overline{T} = 0, \qquad (16)$$

The complete sum of f is obtained via the improved Tison method [11]:

$$\begin{aligned} CS(f) = {} & O\,\overline{F} \vee O\,L \vee N\,\overline{H} \vee N\,\overline{L} \vee C\,\overline{O} \vee C\,\overline{T} \vee \overline{C}\,\overline{N} \vee \overline{C}\,\overline{S} \vee NO \\ & \vee \overline{N}\,\overline{O} \vee S\,T \vee \overline{S}\,\overline{T} \vee \overline{C}\,T \vee C\,S \vee \overline{O}\,\overline{S} \vee \overline{O}\,T \vee \overline{N}\,\overline{T} \\ & \vee \overline{N}\,S \vee C\,\overline{F} \vee C\,L \vee C\,N \vee \overline{N}\,\overline{F} \vee \overline{N}\,L \vee \overline{F}\,\overline{S} \vee \overline{F}\,T \\ & \vee L\,\overline{S} \vee L\,T \vee N\,\overline{S} \vee N\,T \vee \overline{C}\,\overline{H} \vee \overline{O}\,\overline{H} \vee \overline{T}\,\overline{H} \vee \overline{F}\,\overline{H} \\ & \vee L\,\overline{H} \vee \overline{C}\,\overline{L} \vee \overline{O}\,\overline{L} \vee \overline{T}\,\overline{L} \vee \overline{F}\,\overline{L} \vee \overline{C}\,O \vee \overline{T}\,O = 0. \end{aligned} \qquad (17)$$

Equation (17) ferrets out all the prime consequents that can be deduced from the original premises, and they are of a relatively huge number indeed. Each of these consequents makes sense in the view of the original premises. For example, $L\,\overline{H} = 0$ indicates that $L \rightarrow H$, i.e. if the gratuity has a limit, it is at the half-month rate. Note that if one adds a premise about the continuity of service, by asserting either C or $\overline{C}$, then more tangible and decisive conclusions can be reached. However, the "clever" lawyers at the so called "legal" department of the company deliberately refuse to settle the question of continuity and arbitrarily decide to assert T and N as additional premises. These new premises appear in equational form as $\overline{T} = 0$ and $\overline{N} = 0$, and when the disjunction comprising the function f is augmented by them, the formula of f includes now the three terms $N\,T$, $\overline{T}$, and $\overline{N}$ which sum up to 1, and hence:

$$CS(f) = 1,$$

which leads to the contradiction 1 = 0. This means that the total set of premises is inconsistent, and hence it is totally worthless as a basis of deduction [3]. Such a set of inconsistent premises can be used to validly yield any conclusion, no matter how irrelevant. In fact, inconsistent premises can be used to conclude simultaneously any proposition D ($\overline{D} = 0$) and its denial $\overline{D}$ ($D = 0$), since both the terms $\overline{D}$ and D subsume (are included in) the term 1. The "clever" lawyers are now at leisure to forward any unfair decision and disguise it as a valid consequent of their "legal" premises. The engineer should, if he can, insist on (a) showing that there is inconsistency within the given premises, (b) refusing to deduce anything from these premises, and (c) requesting a revision of the premises to ensure their consistency and truth.

4.4. Example 4

Fault tree analysis [15, 16] is a deductive safety analysis technique, which starts at a hazard event and traces backwards to find the events which caused it. The analysis is represented in a diagrammatic form, with symbols representing the events, and logic gates showing the relationships between the events. A fault tree is built from a top level undesirable event simply called the top event. The top level event is decomposed using a series of guidelines which help to identify the contributing factors leading to the undesirable event. For each event in the tree, the immediate causes for this event are identified and determined to be either necessary or sufficient causes. If all identified cases are preconditions for the occurrence of the higher level event, these are considered to be necessary causes and they are conjoined in the fault tree diagram using a logical AND-gate. If individual causes can each result in the higher level event, these are deemed to be sufficient causes, and the relationship between these causes is represented in the fault tree diagram with an OR-gate. There are other gates which are used to represent other causal relationships, such as EXCLUSIVE-OR and PRIORITY-AND.

Many practical fault trees are very complex and involve literally thousands of gates and events. However, we will deal here with a very small example of a portable kerosene heater. This heater has the potential problems of being mistakenly filled with an improper fuel, tipping over, or causing carbon monoxide buildup [14]. These potential problems correspond respectively to the top events or consequences of explosion (X), fire (F), and asphyxiation (A). Figure 2 depicts a combination of three fault trees (called a fault forest) for these three top events. Mathematically, the top events are given in terms of the basic events defined in Fig. 2 as:

$$A \equiv Y\,\overline{S}\,(E\,C \vee \overline{E})\,, \tag{18a}$$

$$F \equiv Y\;\,(E\,C \vee \overline{E})\;\,T\,, \tag{18b}$$

$$X \equiv Y\,E\,\overline{C}\,, \tag{18c}$$

where

$$Y \equiv U\,O\,. \tag{18d}$$

Equations (18a-18c) constitute our set of premises, and can be combined into a single equation of the form:

$$g = (A \oplus Y\,\overline{S}\,(E\,C \vee \overline{E})) \vee (F \oplus Y\,(E\,C \vee \overline{E})\,\mathrm{T}) \\ \vee (X \oplus Y\,E\,\overline{C}) = 0. \tag{19}$$

The function g in Eq. (19) can now be recast into complete-sum form (e.g. by the improved Tison method), so that Eq. (19) becomes:

$$CS(g) = (\overline{A}\,Y\,\overline{S}\,C \vee \overline{A}\,Y\,\overline{S}\,\overline{E} \vee \overline{F}\,Y\,T\,C \vee \overline{F}\,Y\,T\,\overline{E} \vee \overline{X}\,Y\,\overline{C}\,E) \\ \vee (A\overline{Y} \vee A\,S \vee A\,\overline{C}\,E \vee F\,\overline{Y} \vee F\,\overline{T} \vee F\,\overline{C}\,E \vee X\,\overline{Y} \vee X\,\overline{E} \vee X\,C) \\ \vee (F\;X \vee A\,X \vee F\,\overline{S}\,\overline{A} \vee A\,\overline{F}\,T \vee \overline{F}\,T\,Y\,\overline{X} \vee \overline{A}\,Y\,\overline{S}\,\overline{X}) = 0. \tag{20}$$

The prime consequents in Eq. (20) are partitioned with parentheses into three sets:

a) The first set is a set of prime consequents representing:

$$\overline{A}\,CS(A) \vee \overline{F}\,CS(F) \vee \overline{X}\,CS(X) = 0, \tag{21}$$

where $CS(A)$, for example, represents $CS(Y\,\overline{S}\,(E\,C \vee \overline{E})) = Y\,\overline{S}\,(C \vee \overline{E})$. The terms in this set correspond to the minimal cutsets of the individual fault trees. For example, the prime consequent $\overline{A}\,Y\,\overline{S}\,C = 0\;(Y\,\overline{S}\,C \;\rightarrow\; A)$ indicates that the basic events Y, $\overline{S}$ and C constitute a minimal cutset for the top event A, i.e. the simultaneous occurrence of theses three events causes A to occur, but if one of them is missing, A does not occur. Note that some, but not all, of the terms belonging to this first set are visually obvious from the fault trees themselves. To obtain all of these terms, some cutset enumeration technique is needed [17, 18].

b) The second set is a set of prime consequents representing:

$$A\;CS(\overline{A}) \vee F\;\;CS(\overline{F}) \vee X\;\;CS(\overline{X}) = 0, \tag{22}$$

where $CS(\overline{A})$, for example, represents $CS(\overline{Y\,\overline{S}\,(E\,C \vee \overline{E})}) = \;\overline{Y} \vee S \vee \overline{C}\,E$. The terms in this set correspond to what might be called "minimal tie sets" of the individual fault trees. For example, the prime consequent $A\overline{Y} = 0\;(\overline{Y} \to \overline{A})$ indicates that non-occurrence of the basic event Y guarantees the non-occurrence of the top event A. The terms in this second set are not directly obtainable from the fault trees, as they require an algebraic process of negation or complementation associated with complete-sum generation.

c) The third set is a set representing:

$$F\,X \;\vee A\,X \;\vee F\,\overline{S}\,\overline{A} \;\vee A\,\overline{F}\,T \;\vee \overline{F}\,T\,Y\,\overline{X} \;\vee \overline{A}\,Y\,\overline{S}\,\overline{X} \;= 0. \tag{23}$$

This third set has prime consequents involving literals for more than one top event. These consequents are quite hidden within the initial premises. They include two consequents of particular interest, namely, $F\,X = 0$ and $A\,X = 0$. These two consequents tell us what information we have about top events in the absence of information about basic events: (a) Fire and explosion cannot occur simultaneously, and (b) Asphyxiation and explosion cannot occur simultaneously.

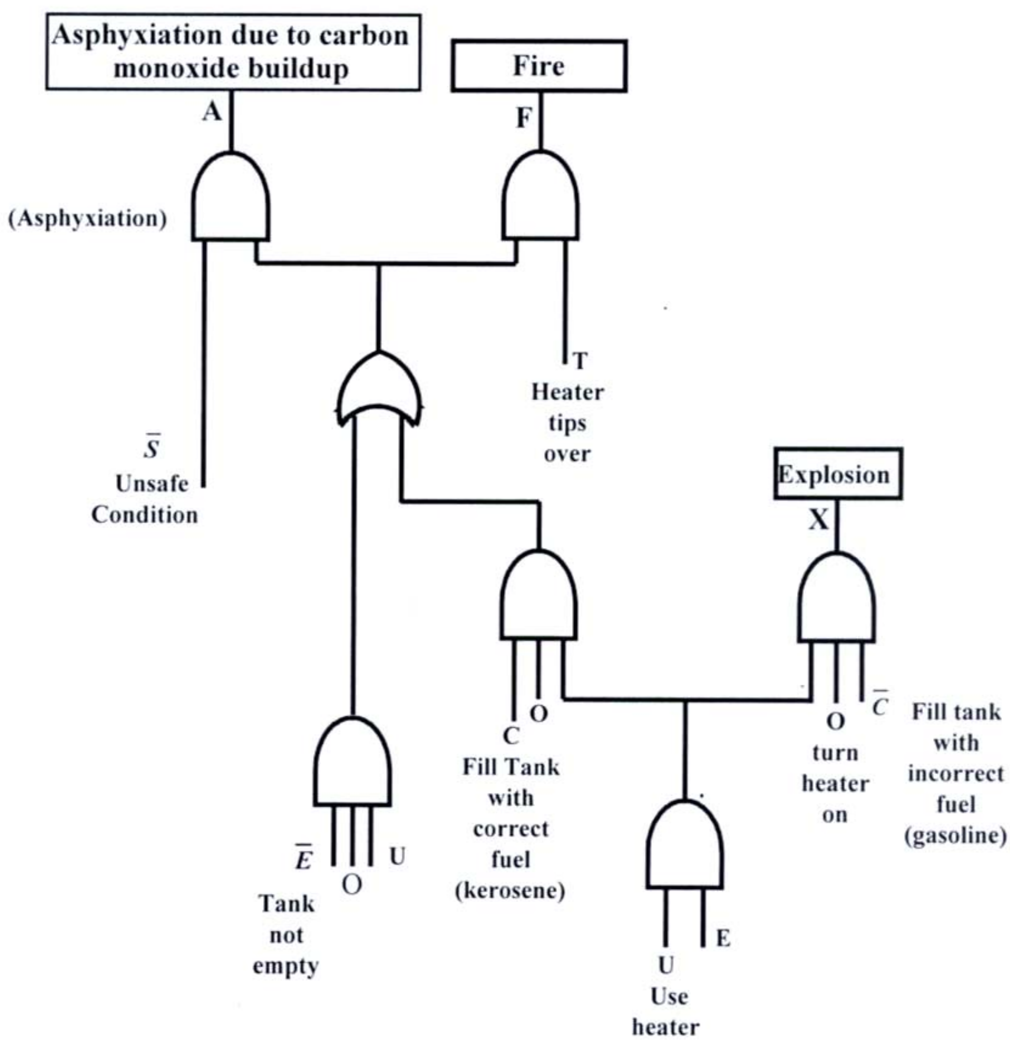

Fig. (2). A fault forest associated with a kerosene heater.

4.5. Example 5

Your company is one of two leading companies that are having almost equal market shares for a certain popular product. To obtain a competitive edge over your rival, you want to join arms with three smaller companies X, Y and Z, so as to form a new consortium of companies or a mega-company. However, your main competitor has exactly the same idea, and plans to establish a similar alliance with three companies A, B and C which are essentially of similar size, technical expertise, and resources as those of companies X, Y and Z. Due to certain market forces government regulations, and conflicts of interests, the following restrictions exist about the participation of the six small companies in the two alliances:

1. If neither A, B nor C joins the rival alliance, then Y and Z join yours, but X does not.
2. If A joins the rival alliance together with either B or C or both, then Y does not join your alliance, and either X does not join it or Z joins it.
3. If B joins your competitors but A does not, or C joins them but B does not, then both X and Y join you, or neither X nor Z does.
4. If C allies with your rival together with A or B or both, or if neither A nor C joins, then either X does not join you, or Y does but Z does not.
5. If A joins the rival alliance but B does not, then X does not join you or Z does.

Now, we pose the following three questions:

a) In the absence of any information about the participation of companies A, B and C in the rival alliance, what can you conclude about the participation of companies X, Y, and Z in your alliance?
b) You are currently contemplating awarding a contract to one of the X, Y, and Z companies, and you believe that the company awarded that contract is definitely guaranteed to join your alliance. Which company would you choose to maximize the participation in your alliance?
c) If you implement the action suggested in (b), and given no further information, what can you conclude about participation of the A, B, and C companies in the rival alliance? Is your alliance bigger than the rival one?

To answer these questions, we formulate the given premises (1-5) as follows:

1. $\bar{A}\,\bar{B}\,\bar{C} \quad \to \quad \bar{X}\,Y\,Z$,
2. $A\,(B \vee C) \quad \to \quad \bar{Y}\,(\bar{X} \vee Z)$,
3. $\bar{A}\,B \vee \bar{B}\,C \quad \to \quad X\,Y \vee \bar{X}\,\bar{Z}$,
4. $C\,(A \vee B) \vee \bar{A}\,\bar{C} \quad \to \quad \bar{X} \vee Y\,\bar{Z}$,
5. $A\,\bar{B} \quad \to \quad \bar{X} \vee Z$.

The premises combine into a single equation $f = 0$ where:

$$f = \bar{A}\,\bar{B}\,\bar{C}\,(X \vee \bar{Y} \vee \bar{Z}) \vee A\,(B \vee C)\,(Y \vee X\,\bar{Z}) \vee (\bar{A}\,B \vee \bar{B}\,C)\,(X\,\bar{Y} \vee \bar{X}\,Z)$$
$$\vee (A\,C \vee B\,C \vee \bar{A}\,\bar{C})\;X\,(\bar{Y} \vee Z) \vee A\,\bar{B}\,X\,\bar{Z}, \tag{24}$$

The function has the complete sum [4, 12]:

$$CS(f) = A\,C\,X \vee A\,X\,\bar{Z} \vee A\,C\,Y \vee A\,\bar{B}\,C\,Z \vee A\,B\,Y \vee \bar{A}\,X\,\bar{Y} \vee C\,X\,\bar{Y}$$
$$\vee X\,\bar{Y}\,\bar{Z} \vee \bar{A}\,\bar{Y}\,Z \vee \bar{B}\,C\,\bar{Y}\,Z \vee \bar{A}\,C\,\bar{X}\,Z \vee C\,\bar{X}\,Y\,Z$$
$$\vee \bar{B}\,C\,\bar{X}\,Z \vee \bar{A}\,\bar{B}\,\bar{C}\,X \vee \bar{B}\,\bar{C}\,X\,\bar{Z} \vee \bar{A}\,\bar{B}\,\bar{C}\,\bar{Y} \vee \bar{A}\,\bar{B}\,\bar{C}\,\bar{Z} \tag{25}$$
$$\vee \bar{A}\,B\,Z \vee B\,C\,X\,Z \vee B\,Y\,Z \vee \bar{A}\,\bar{C}\,X\,Z.$$

In (a), we lack any information about A, B and C. Therefore, we eliminate the variables A, B and C by deleting every prime implicant involving A, B or C from the equation *CS(f)* = 0. This produces the result:

$$X\,\overline{Y}\,\overline{Z} = 0, \tag{26}$$

which can be stated in the conditional form:

$$X \rightarrow Y \vee Z, \tag{27a}$$

which means that (in the absence of information about the rival participation) if company X joins you, then company Y or company Z or both will also join you. Equation (26) can also be stated in either of the equivalent conditional forms:

$$\overline{Y} \rightarrow \overline{X} \vee Z, \tag{27b}$$

$$\overline{Z} \rightarrow \overline{X} \vee Y\,, \tag{27c}$$

which we will not explore further since they are not pertinent to the decision requested in question (b). In fact, to answer question (b), let us consider what happens if company Y is selected by assigning the value 1 to Y in Eq. (26). This reduces Eq. (26) to the identity 0=0, which says that if Y is selected, there will be no information of what will become of X and Z. Similarly, if company Z is selected, we obtain no information about the participation of X and Y. Therefore, it is prudent to award the contract to company X so as to guarantee its participation, since this will trigger the participation of at least one of the two other companies, and hence you get two or three companies joining your alliance. If you grant the contract to either Y or Z, you guarantee the participation of only the single company awarded the contract.

To answer question (c) assuming that your decision in (b) is to ensure the participation of X, we restrict X to the value 1 in Eq. (25), to obtain (after the absorption of subsuming terms):

$$CS(f) = A\,C \vee A\,\overline{Z} \vee A\,B\,Y \vee \overline{A}\,\overline{Y} \vee C\,\overline{Y} \vee \overline{Y}\,\overline{Z} \vee \overline{A}\,\overline{B}\,\overline{C} \vee \overline{B}\,\overline{C}\,\overline{Z} \vee \overline{A}\,B\,Z \vee B\,C\,Z \vee B\,Y\,Z \vee \overline{A}\,\overline{C}\,Z. \tag{28}$$

Now we locate the prime implicants in Eq. (27) that involve variables A, B and C only. This gives us the results:

$$A\,C = 0\,, \tag{29}$$

$$\overline{A}\,\overline{B}\,\overline{C} = 0\,, \tag{30}$$

which means that in the absence of any further information, the rival alliance will not be joined simultaneously by A and C, though it will be joined by at least one of the three companies A, B and C. This means that your competitor recruits one or two companies to join his alliance. Your alliance, however, is joined by two or three companies. Your alliance is most likely bigger than, or at least equal to, your competitor's alliance.

5. Conclusions

This paper describes the modern syllogistic method, which ferrets out from a given set of premises all the consequents that can be concluded from this set, and casts these consequents in the simplest or most compact form. The modern syllogistic method can deal with arguments of many varieties on many different topics, but it is restricted herein to the engineering subject matter. We believe that the modern syllogistic method can serve as a useful and powerful tool for the engineer, as it can help him reason well and correctly about his specific discipline. Due to space limitations, the paper presents only a quick glimpse of the many possible engineering applications of the method. Notable among the ones excluded here is the application of the method to problems of controllability and observability in automatic control [19] and to the resolution of engineering ethical dilemmas [20].

We are currently investigating the utility of the modern syllogistic method in avoiding the trap of illusory inference, which is a class of erroneous deductions that are compelling but invalid [21, 22]. We are also trying to make use of the modern syllogistic method in the study of enthymemes, which are arguments, or chains of argumentation, with one or more missing (implicit) premises or conclusions [23]. Our target is to devise a general technique to fill in missing premises in an enthymeme subject to some reasonable criterion of acceptability. Work on this problem is promising, since it is quite related to the well-developed problem of finding a best-fit extension of a partially defined Boolean function [24].

6. References

[1] Holtzapple, M. T. and Reece, W. D. *Foundations of Engineering.* 2nd ed., Boston, MA, USA: McGraw-Hill, 2003.

[2] Al-Maidani, A. H. H. *Knowledge Constraints and Fundamentals of Deduction and Debating: A Formulation of Logic and Research Fundamentals Compatible with Islamic Ideology.* Damascus: Darul Qalam (in Arabic), 1993.

[3] Copi, I. M. and Cohen, C. *Introduction to Logic.* 12th ed., Upper Saddle River, NJ, USA: Prentice-Hall, 2005.

[4] Brown, F. M. *Boolean Reasoning: The Logic of Boolean Equations.* Boston, MA, USA: Kluwer Academic Publishers, 1990 (2nd ed. by Mineola, NY: Dover Publications, 2003).

[5] Gregg, J. R. *Ones and Zeroes: Digital Circuits and the Logic of Sets.* New York, NY, USA: Wiley, 1998.

[6] Rushdi, A. M. and Al-Shehri, A. S. "Logical Reasoning and Its Role in Serving Security and Justice." *Security Research Journal,* 11, No. 22 (2002),114-153 (in Arabic with an English abstract).

[7] Rushdi, A. M. "Using Variable-Entered Karnaugh Maps to Solve Boolean Equations." *International Journal of Computer Mathematics,* 78 (2001), 23-38.

[8] Klir, G. J. and Marin, M. A. "New Considerations in Teaching Switching Theory." *IEEE Transactions on Education,* E-12, No. 4 (1969), 257-261.

[9] Muroga, S. *Logic Design and Switching Theory.* New York, NY, USA: John Wiley and Sons, 1979.

[10] Rushdi, A. M. "Prime-implicant Extraction with the Aid of the Variable-entered Karnaugh Map." *Journal of Umm Al-Qura University: Science, Medicine and Engineering,* 13, No. 1 (2001), 53-74.

[11] Rushdi, A. M. and Al-Yahya, H. A. "Derivation of the Complete Sum of a Switching Function with the Aid of the Variable-entered Karnaugh Map." *Journal of King Saud University: Engineering Sciences,* 13, No. 2 (2001), 239-269.

[12] Rushdi, A. M. and Al-Shehri, A. S. "Selective Deduction with the Aid of the Variable-entered Karnaugh Maps." *Journal of King Abdul-Aziz University: Engineering Sciences*, 15, No. 2 (2004), 21-29.

[13] Thayse, A. "Meet and Join Derivatives and Their Use in Switching Theory." *IEEE Transactions on Computers,* C-27, No. 7 (1978), 713-720.

[14] Fogler, H. S. and Leblanc, S. E. *Strategies for Creative Problem Solving.* Upper Saddle River, NJ, USA: Prentice-Hall PTR, 1995.

[15] Rushdi, A. M. "Uncertainty Analysis of Fault-tree Outputs." *IEEE Transactions on Reliability,* R-34, No. 5 (1985), 458-462.

[16] Ebeling, C. E. *An Introduction to Reliability and Maintainability Engineering.* New York, NY: McGraw-Hill, 1997.

[17] Rauzy, A. "Mathematical Foundations of Minimal Cutsets." *IEEE Transactions on Reliability*, 50, No. 4 (2001), 389-396.

[18] Zhihua, T. and Dugan, J. B. "Minimal Cutset/Sequence Generation for Dynamic Fault Trees." *Annual Reliability and Maintainability Symposium,* (2004), 207-213.

[19] Rushdi, A. M. and Ba-Rukab, O. M. "Some Engineering Applications of the Modern Syllogistic Method." *SEC7 Paper 226, Proceedings of the Seventh Saudi Engineering Conference (SEC7),* Riyadh, KSA, 4 (2007), 389-401.

[20] Rushdi, A. M. and Baz, A. O. "Computer Assisted Resolution of Engineering Ethical Dilemmas." *SEC7 Paper 147, Proceedings of the Seventh Saudi Engineering Conference (SEC7),* Riyadh, KSA, 5 (2007), 409-418.

[21] Johnson-Laird, P. N. and Savary, F. "Illusory Inferences: A Novel Class of Erroneous Deductions." *Cognition,* 71 (1999), 191-229.

[22] Barrouillet, P. and Lecas, J.-F. "Illusory Inferences from a Disjunction of Conditionals: A New Mental Models Account." *Cognition,* 76 (2000), 167-173.

[23] Walton, D. "The Three Bases for the Enthymeme: A Dialogical Theory." *Journal of Applied Logic,* (in press), available online on June 21, 2007.

[24] Boros, E.; Ibaraki, T. and Makino, K. "Error-free and Best-fit Extensions of Partially Defined Boolean Functions." *Information and Computation,* 140 (1998), 254-283.

الطريقة الاستدلالية ا ديثة كأداة ل ا سائل ا ندسية

علي مد رشدي*، عمر مد باروكاب**

*قسم ا ندسة الكهربائية وا اسب الآ ، كلية ا ندسة

جامعة ا لك عبد العزيز، جدة- ا ملكة العربية السعودية

**كلية الاتصالات والإلكترونيات، جدة، ا ملكة العربية السعودية

(قُدم للنشر في ٢٠/٦/٢٠٠٧م ؛ وقُبل للنشر في ٦/١١/٢٠٠٧م)

ملخص البحث. نقدم وصفًا للخطوات والملامح الأساسية للطريقة الاستدلالية الحديثة التي تمثل أسلوبًا قويًّا للاستدلال الاستنباطي. تستخرج هذه الطريقة من مجموعة من المقدمات كل ما يمكن استنتاجه منها ، وتصوغ الاستنتاجات الناجمة في أبسط صورة ملمومة. نبين إمكانية تطبيق هذه الطريقة في مسائل هندسية متنوعة باستخدام خمسة أمثلة توضح التفصيلات الرياضية للطريقة ، كما تفصح عن طبيعة الاستنتاجات التي يمكن أن تأتي بها. يتم بيان أن هذه الطريقة تفيد بصفة خاصة في اكتشاف وجود عدم انسجام في مجموعة من المقدمات أو الافتراضات ومن ثم فإنها تعين القائم بحل مشكلة معينة على التوصل إلى جوهر المشكلة ، كما أنها تساعد المهندس في مواجهة المحاجة المبنية على المغالطة. ويجري أيضًا توضيح كيف تسفر الطريقة عن نتائج مثمرة عندما يتم إدماجها مع أسلوب الأمن والسلامة المعروف باسم تحليل شجرة الأخطاء. تُستعمل الطريقة أيضًا في الاستنباط الاختياري وفي اتخاذ القرارات المعضدة بالمعرفة.

المحتويات

[illegible]

المجال فإن المجلات العلميةُ المتخصصة تحقق هذا الغرضِ وتوفر فرصة التواصل العلميِ، ومن هذا المنطلق كان توجه جامعة القصيم نحو إصدار مجلة علوم الهندسة والحاسب الآلي.

إنّ الأهدافَ الرئيسية للمجلة هو تشجيع البحث العلمي النظري والتطبيقي في مجالات الحاسوبَ والهندسة، ونشر مساهمات الباحثين والمتميزين لزيادة رقعة المعرفة في المجتمعات العلمية والصناعية.

إنّ مجال المجلة يغطّي العديد من التخصصات: الهندسة الميكانيكية والكهربائية والمدنية والكيميائية والتعدين وهندسة النفط وهندسة الحاسوب وعُلوم الهندسة الأساسية، وأيضاً المجلة مهتمّة بتخصصات علوم الحاسبَ التي تتضمّنُ تقنية وأنظمة المعلومات.

ويتوجه أعضاء هيئة تحرير المجلة بخالص الشكر والامتنان إلى معالي مدير الجامعة وسعادة وكيل الجامعة للدراسات العليا والبحث العلمي والمديرين التنفيذيين بجامعة القصيم وأيضاً إلى سعادة عميدي ووكلاء كُليتي الهندسة والحاسبِ، لدعمهم المستمر والفعال لإصدار المجلة وتوجههم الصادق للدفع بالمجلة نحو العالمية.

ÀΛÀHuQöä ĞÄɆŁ ÈɆəø

ȽɆŸΣäÆG3 ƷɆȴÊöäÆG3 ÆȴƮ .ǻ .Ǖ

تصبح إقليمية بل ودولية كذلك، وفى نفس السياق فان التطبيب عن بعد يخطو خطواته الأولى (ومثال ذلك: مراقبة مريض عن بعد)، ولكن من المتوقع أن تزداد أهميته لاحقاً.

• طرق معالجة الإشارات والتي تؤدي إلى اتصالات ذات اعتمادية عالية في وجودِ تشويهِ سمعيٍ يجِب أن تبحث باستفاضة وبتم التركّيزَ على الاستغلال المثالي لمصادر الاتصال المحدودة (نطاق الترددات والطاقة)، تتضمّنُ مجالاتُ البحثِ التضمين والكشف التكييفي والتشفير ذي الكفاءة العالية، والمعالجة الشعاعية، وإخماد تداخل الموجات في الوصلات عالية المعدل وشبكات الاتصال، ويدخل أيضاً تطوير طرق ضغطِ البيانات بالإشارات الصوتية والمرئية في تلك الاهتمامات، ويتطلب الإحساس والتصوير تحت الماءِ الموازنة بين أعلى نسبة من ضغط المعلومات مع الاعتمادية العالية واستهلاك الطاقة.

• إن الإمكانيات التي توفرت بواسطة الحاسبات وتطبيقات البرمجيات والاتصالات عن بعد وإعادة تصميم عمليات السوق، كل هذه الأدوات لها القدرة على خلق نوع جديد من الهندسة الصناعية مغيراً الطريقة التي يمارس بها هذا التخصص، والمهارات اللازمة له. هؤلاء الذين يتطلعون إلى تحسين الطريقة التي يتم بها العمل، يجب أن يبدأوا بتطبيق إمكانيات تكنولوجيا المعلومات لإعادة تصميم عمليات السوق. إن تصميم عمليات السوق و تكنولوجيا المعلومات هما شريكان طبيعيان، حتى وإن كان المهندسون الصناعيون لم يكتشفوا كامل تلك العلاقة.

• أي تغيير رئيسي في التصميم والتصنيع حدث أثناء السَنَوات الخمسين الماضية كَان بسبب نمو المحاكاة بالحاسوبِ لأداة التصميم والتقليد بزيادَة مناطقِ الدقة الفائقة لأداءِ تصنيع المنتجِ، وقد أدركت الشركات بأنّ ذلك وسيلة فعّالة جداً لإنتاج المنتجات الأفضل بتكلفة أقل. إنّ أهمية علوم الحاسب مستمرة التزايد بصورة كبيرة، ويستمر اكتشاف الطرقَ لبناء وتحديث كُل شيءَ ينتج من الآليات البسيطة الصغيرة المجمعة معاً باستخدام البرامجِ، وليس هناك أي مشكلة مع العمل معُ علم الحاسب، كما أن هناك مجالات جديدة رائعة مع علوم الحاسب في علوْم الأحياء وتكنولوجيا و فيزياء الجُزيئات، ونود الإشارة إلى أن العمل مع علوم الحاسب سيحقق انخفاض التكاليفَ الطبية، كما يمكن أن يقال أن علوم الحاسب سَتلعب الدورَ الرئيسي. في دعم التعليم العالمي.

إن الجا معات ومراكز البحوث بهما الكثير من الباحثين في كافة التخصصات وخاصة مجالات الحاسب والهندسة، والجُهودَ العلمية التي يقوم بها العديد من الباحثين كثيرة، إلا أن هذه الجهود يمكن أن تتكرر حيث أنها تجرى في أماكن مختلفة حول العالم، لذا يجب وضع نظام للتكامل والتعاون، بحيث يكون أي جهد مبذول هو استكمال لجهد سابق ويكون حلقة من سلسلة واحدة، وبحيث يطلع الباحثون على جهود بعضهم البعض. وفي هذا

• تزايد الطلب على الطاقة والنَقْص العالمي من الوقود التقليدي يتطلب ذلك تطوير الصناعات والخدمات المستخدمة للوقود التقليدي ومنها صناعة السيارات الخالية من الوقودَ الحفري، واستحداث طرق نقل بديلة صديقة للبيئية ومصادر طاقة جديدة. كما إنّ زيادة الأعدادَ المتوقّعة للسيارات الخاصّة يستلزم ضرورة زيادَة كفاءة أنظمة إدارة المرور المستخدمة، وهناك أيضاً الحاجة الفعالة للحد من عادم غازات السيارات لتحسين أمنِ مستعملي الطرقِ، ويشمل التطوّرَ السائقِ والأنظمة التشخيصية الفورية والسيارات المصنعة من المواد الجديدة المحسَّنة والصديقة للبيئة، ومثل هذه التقنيات سَتؤدّي إلى سيارات وطائرات وسُفنِ ذات كفاءة بيئية عالية.

• شهدت الهندسة المدنية تطورات كثيرة منذ أن بنا الرومان الطرق والموانئ والقنوات عبر أوروبا، ومازال الاهتمام الخاص بالهندسة المدنية منصباً على خدْمة الزبائنِ ومساعدُتهم لإدْراك أفكارهم، سواء كان المشروع صغيراً أو كبيراً، ومع ذلك هناك بَعْض سمات المهنة تتغيّرَ بشكل كبير مع اكتشاف الموادِ الجديدة مثل أنسجة الفولاذ، وتقنية الحواسيب الشخصية وبرامج التصميم المختلفة. أثناء العقد الحالي أدت التقنيات الحديثة إلى تطور عديد من الممارسة العملية وتطبيقِات الهندسة المدنية كما وكيفا، وعلى المهندسين والمؤسسات الهندسية الاستعداد للعقدِ الرقميِ وامتلاك القدرة على إرضاء العميل وحصد الأرباحَ.

• لقد بدأت ثورة لاسلكي الهواتف الخلوية فقط منذ ١٥ سَنَة، وخلال هذا الوقت القصير تغير الهاتف الخلوي من رمز اجتماعي إلى احتياج ضروري. إن التقدم الهائل في التحويل الرقميِ وتقنيات وعلم الالكترونيات أدى إلى الوصول لدقة المعالجة والكلفة المناسبة، وفي هذا المجال يستمر العمل على تقدم مجموعات اتصال الأقمار الصناعية والهواتف الخلوية من اجل التزود بخدمات أكثر تطَوُّراً من مكالمات هاتفية وإذاعة صوتية واتصال بالإنترنت والتلفزيون.

• كنتيجة للتقدم التكنولوجي السريع، أنظمة الاتصال المختلفة لتجميع ونقل وتَخزيْن ومعالجة المعلومات تتوحد وتتقارب، إن معالجة الصوت والصورة والبيانات على شبكة اتصال حاسوبِ واحد قد أدى إلى العديد من التطبيقات في سوق العمل والصناعات المدنية والعسكرية. وبمكن الآن للمنظمات ذات المئات من المكاتب المنتشرة في مناطق واسعة َعْقدَ اجتماعات ورُؤية وسماع بعضهم البعض وحتى الكتابة على سبورة افتراضية مشتركة عن طريق المؤتمر المرئي، وأيضا المؤتمرات عبر الفيديو المدعومة بالحاسوب تعتبر أداة فعالة لتوفير الكلفة والوقت الخاص بالسَفَر، ولقد اكتشفت شركات الطيران والأزياءَ والمكتبات أن العملاء يحبون التسوق المريح وهم في منازلهم، وكنتيجة لهذا فإن شركات عديدة تنشر كتالوجات لبضائعها وخدماتها علي الشبكة الدولية، وتتلقى الطلبات عليها مباشرة. إن التعليم سوف يتأثر بالاتصال عن بعد بشكل جذري والجامعات سوف

• إحدى أكثر المهام صعوبة ستكون تحويل اعتمادِ الصناعات الهندسَية القائمة حالياً والتي تستخدم الوقود الحفري إلى استخدام أنظمة الطاقات الجديدة، ولتحقيق ذلك هناك ثلاث اتجاهات يمكن أن تتبع : الاتجاه الأول تخفيض الاعتماد على النفطِ كمادة خام في الصناعات الكيماوية بالتحول التدرجي إلى الغاز الطبيعي أو الفحم أَو المواد العضوية، وهذا يستلزم العديد من التعديلات التقنية في طرقِ الإنتاج، والاتجاه الثاني استخدام الوقودِ الحيوي لتوليد الطاقة، والاتجاه الثالثَ تطوير التقنيات التي تمكن منُ إنتاجَ الهيدروجينِ في شكل آمن وسهل الاستخدام كوقودِ.

• إن التقنيات الحديثة (تقنيات السيطرة والتحكم والتقنيات التحليلية لإنتاجِ الموادِ الأولية) سوف تلعب دوراً حيوياً في إدارة ترشيد الطاقة في المستقبل، وسيشمل ذلك العمل على رفع كفاءة العمليات الأكثرَ شيوعا إلى إدراك التطورات الجديدة لأغشية خلايا الوقودِ.

• تعتبر صناعة الإلكترونيات إحدى الصناعات الهامة والأسرع تطوراً، وهى من الصناعات الإبداعية في العالم ويرجع ذلك إلى الاكتشافات المتعددة لصناعة الموادِ متعددة الوظائف، مثل السيليكون لتخزينِ البيانات البصرية والبلورات السائلة للعروضِ والمشاهدة لذا فان التطَوّرات في الصناعات الإلكترونية سيؤثر على المنتجات الجديدة والتقنيات.

• من المعروف أن كفاءة الإضاءة تعتمد على شكل الضوءِ المنبعث ولذا يمكن أن تستبدل المصابيحَ المعتمدة على سلكِ التنجستن والأنابيبِ المشعة للحرارة بتقنيات حديثة لتوفير الطاقة، وأيضا الحصول على الإضاءة الخفيفة باستخدام الطلاءات المناسبة أَو النوافذ ذات الوظائف الذكية، واستخدام أنظمة جديدة صلبة تستطيع تحويل الحرارة إلى الكهرباء يمكن استخدامها في عمليات التبريد والسيطرة الدقيقة على درجة الحرارة لتوفير الطاقة.

• إحدى أكثر القضايا الملحة والهامة التي تواجهُ العالم هي توفير الماء الصالح للشربِ من خلال تطوير الأنواع الجديدة لعمليات الترشيح وتقنيات استخدام الأغشية، والتي تأخذ في الاعتبار كل من الكفاءة والتكلفة لتحويل ماءِ البحر إلى ماءِ صالح للشربِ. كما أنّه هناك جهود لتطويرَ صناعة الثلاجات الموفرة للطاقة، وإنتاج الثلاجة الذكية القادرة على مرَاقَبَة الغذاءِ بصورة جيدة وإصدار تحذير عندما يبْدأُ الغذاء بالتحلل، وإضافة ميزّة للثلاجة حيث سَتكُونُ قادرة على مرَاقَبَة المواد الغذائية، وإصدار التعليمات لطَلب أيّ من هذه المواد عندما تنفذ.

كلمة رئيس هيئة التحرير

الهندسة والحاسب يعنيان مستقبلاً مشرقاً

هناك العديد من أبحاث الهندسة والحاسب التي تم تطويرها بسرعة هائلة خلال الآونة الأخيرةً، وتم تطبيقها في كثير من نواحي الحياة المعاصرة لزيادة الكفاءة والاحتفاظ بالسعر المناسب، هذا التطور السريع في علوم وتقنيات الهندسة والحاسب، وارتباطهما معا يلعبانِ دوراً واضحاً جداً في الرفاهية والنمو الاقتصادي العالمي، وتندرج تلك الأبحاث والتطورات تحت العديد من المجالات الهندسية ومجالات علوم الحاسب، وعلى سبيل المثال وليس الحصر نستعرض فيما يلي بعضاً من موضوعات هذه الأبحاث وملامح التطور:

- إن الطاقة ستصبح سلعة إستراتيجية خلال الأعوام القليلة القادمة سواء كانت الطاقة على شكل كهرباءِ أو حرارة أو ضوء أو طاقة ميكانيكية، ومن هذا المنظور فان هناك حاجة ماسة لإدارة مصادر الطاقة بكفاءةً عالية، كما يجب التركيز على المنتجات الجديدة المصنعة من الموادِ الحديثة، والتي تؤدي إلى تخزين واستهلاك ونقل للطاقة بطريقة فضلىٍ.

- بعد ربط البحوث العلمية في مجالات الهندسةِ وعلم الحاسبات والكيمياء الحيويةُ تم استخدام موادِ متقدّمة في إيجاد أنظمة جديدة للطاقة، ومن ثمرة هذا التعاون استحداث مصادر جديدة بديلة للطاقة مثل الخلايا الشمسية وخلايا الوقودِ ومنتجات أولية للطاقة و هذه البدائل تبشر بإمكانيةُ عظيمةُ في التطبيقات الحياتية اليومية خلال السَنَوات القادمة. وسوف تعتمد درجة نجاحِ تطبيقِ التقنيات الجديدة للطاقة على الإنجازات التي تمت في علم الهندسة لحل المشاكل الحالية للأداءِ والاستقرار والتكلفِة لأنظمة الطاقة المستحدثة، وعلى سبيل المثال الخلايا الشمسية يمكن أَنْ تكون بديلاً عن الوقود في بعض المجالات، ولذا كان من الضروري العمل لتطوير طرقِ إنتاجِ السيليكون البلوريِ المستخدم في تطوير موادِ السيليكون اللاشكلية الهجينة وكذلك إنتاج الأصباغِ الأرخصِ والأكثر ثباتاً، وتحسينَ كفاءة صبغ الخلايا.

٢. مجال استعمال التفاعلات النووية ذات الطاقة المنخفضة، والذي يفترض أن تضاعف الطاقة المدخلة إلى عشر مرات، حسب ما صرح به مؤخراً في انجلترا، وإذا تم التأكد من هذا الاكتشاف، فإن عالمنا سيكون مغايراً تماماً لما هو عليه الآن، وسنشاهد نهاية عصر النفط، مما سيؤدي بنا إلى شرب النفط لا إلى حرقه كبنزين!

وفي هذا الصدد، فلا انجازات الهندسة ولا اكتشافات الحاسب تستطيع التأثير في حياة الإنسان دون المجلات العلمية. لقد ساعدت المجلات العلمية في نقل هذه الانجازات إلى جميع أنحاء العالم، وإضافة إلى ذلك، فإن المجلات العلمية تؤدي دورا هاما في تطوير المؤسسات الأكاديمية لأنها تعتبر نافذة البحوث العلمية لأعضاء هيئة التدريس والطلاب والمنظمات الصناعية المختلفة، ونأمل أن يكون لهذا العدد الأول من المجلة الصدى الإيجابي في المحيط الأكاديمي في جامعة القصيم وخارجها، ونحن نقدر أي تعليقات واقتراحات لتحسين نوعيتها وجعلها مجلة دولية.

ǦĦŋÅƨä ÕÊȬş

Ŋŋ̊äÆöä !äÆĢʒ ȸä ſÅò .á .ů

كلمة وكيل الجامعة للدراسات العليا والبحث العلمي

" التحديات الهندسية للقرن الحادي والعشرين"

يسرنا إصدار العدد الأول من "مجلة جامعة القصيم لعلوم الهندسة والحاسب"، مع أملنا في أن يكون لها بالغ الأثر على الصعيدين العلمي والتطبيقي في المملكة العربية السعودية وفي بقية البلدان الأخرى، إذ تعتبر الهندسة وتكنولوجيات الحاسب إحدى منتوجات المدنية الحديثة، ومن هذا المنطلق، فإنه من الأهمية بمكان أن ندرس ما قدمته هذه التكنولوجيات للبشرية، فعلى سبيل المثال، إن الثورة الصناعية أنتجت الآلات والمحركات المختلفة التي أكملت، بل أحيانا استبدلت، القوى البشرية العاملة، وقد أدى ذلك إلى تحسين المجالات المختلفة للهندسة ومنها مجالات هندسة التنقيب، ومحركات السفن، والقطارات، والمصانع، ونظم الصرف الصحي، مما أدى إلى تحسين رفاهية الإنسان في مجالات الحياة المعاصرة، ومن مجالات الدراسات الهندسية الهامة، والتي من المنتظر أن يكون لها تأثير كبير على حياة الإنسان في المستقبل:

١. مجال *كربون* ٦٠- المعروف باسم Buckminsterfullerene- والذي يتوقع أن يوفر مادة أخف واقوى من المعادن، وسوف يُحدث هذا الانجاز ثورة في كل مجالات الحياة مثل إمكانية الوصول إلى الفضاء القريب من الأرض بواسطة مصعد الفضاء. إن تصنيع الأسلاك من هذا النوع من الكربون سوف يمكن من تقليل حجم الرقائق الدقيقة الحالية مرات عديدة، وبما أن الأنابيب النانو الكربونية، أو النانوتيوب الكربونية (CNT) كانت مجالاً لأبحاث واستعمالات تطبيقية أولية، فإن من مهام هندسة النانو أن تجعل من توسيع تطبيقات النانوتيوب أمرا شائعا، وقد أظهرت الأبحاث أن النانوتيوب الكربونية يمكن استعمالها كأشباه الموصلات في الترنزستورات وهي العناصر الأساسية لكل جهاز حاسب. إن هذا الإنجاز يعتبر أمرا مهما لأن الصناعة تحتاج إلى تكنولوجيات بديلة للحصول على مزيد من الإنجازات. إن تقنيه النانو وحدها من المتوقع أن تنشئ مئات من الاختراعات الجديدة.

سابقاً معلوماً حاضراً. لقد توسعت دائرة التحديات الناتجة عن تطور التعداد البشري، وتزايد حاجة الإنسانية لمتطلبات الحياة، مما جعل الحاجة مستمرة للمزيد من التطوير والإنجاز والابتكار.

ويمكن القول أن الإنجاز العلمي يظل مجهولاً إلى أن يتم نشره في الأوساط المقروءة أو المسموعة أو المرئية، ومن هنا تظهر الحاجة الماسة إلى السعي إلى نشر الإنتاج العلمي والإنجاز الهندسي لإشاعته بين فصائل المجتمع حتى يمكن الاستفادة منها في التطور والارتقاء بالذات البشرية إلى الأفضل.

وفي هذا الإطار دأبت جامعة القصيم كسائر جامعات المملكة الفاعلة والمتفاعلة مع محيطها على إيجاد مناخا مشجعا للابتكار والإشعاع ونشر العلوم والإنجازات الهندسية، وهي إذ تبارك صدور العدد الأول من المجلة العلمية للهندسة والحاسب الآلي تعتبر أن هذا العمل يعد خطوة جديدة على درب التطور والارتقاء بالإنسان إلى الأفضل .

ǦĤŋȦƨā ÀÆŋ

ɃắɀŧΣā ȸƥÀōāÆƷ ȸǣ ÆōȦǹ .ǻ .Ů

كلمة مدير الجامعة

مسيرة على درب الريادة

تلعب المجلات العلمية دور الريادة في تقدم العلوم الهندسية، وذلك بإشاعة العلوم بين الباحثين وأعضاء هيئة التدريس من ناحية والمجتمعات العلمية الأكبر من ناحية أخرى، وفي إطار رسالتها تجاه الطلبة وأعضاء هيئة التدريس والمجتمعات العلمية والصناعية تجتهد جامعة القصيم للدفع الفعال لقيم البحث العلمي إيمانا منها بأهمية نشر شتى العلوم والتخصصات، ويأتي إطلاق مجلة الهندسة وعلوم الحاسب QUJECS بجامعة القصيم دليلاً على إيمانها بجدوى دفع البحث العلمي وإنماء روح الشغف للعلوم والجدية في طلب المعارف لدى طلابها وطالباتها ومنسوبيها من أعضاء هيئة التدريس والباحثين، ويبقى الهدف الأسمى الذي تتطلع إليه جامعة القصيم؛ إيجاد بيئة ملائمة تتلاقى فيها الأفكار وتتنافس فيها الإنجازات لتكون الجسر الرابط بين عالم المبتكرين ومؤسسات المجتمع الفاعلة والمنتجة في المملكة.

وليس من الغريب أن الأكاديمية الوطنية الأمريكية للهندسة عند احتفائها بأهم الإنجازات الهندسية العشرين في القرن الماضي، أعلن رائد الفضاء الشهير نيل أرمسترونغ أن أهم جوانب الحياة البشرية قد شهدت تطورات عميقة خلال المائة سنة الماضية بفضل الإنجازات العلمية والهندسية، هذه الإنجازات المذهلة كانت تعد سابقا من قبيل المستحيل، ثم أصبحت حقيقة فعلية، وأردف الرائد المشهور يقول: وبصفتي أول فضائي يسير على سطح القمر لم يكن عندي أي شك أن إنجازات القرن المقبل ستكون أكثر إثارة وتأثيراً وفائدة.

وجدير بالإشارة أن القرن الماضي قد انتهى بكم هائل من الإنجازات العلمية والهندسية، مثل نقل الطاقة الكهربائية، وتحلية المياه، والإنجازات الصناعية كالسيارات والطيران والراديو والتلفزيون وأشعة الليزر، والمضادات الحيوية، وطرق التشخيص الطبي، والحاسب والانترنت، وغيرها من الابتكارات التي غيرت بشكل جذري مجرى حياة الإنسان المعاصر، ومن خلال هذه الإنجازات والابتكارات أصبح العالم كالقرية الصغيرة، وصار المجهول

(øŁČďčĔ ÿÅŢ / ÿčċċē ÅΛÅΛ) ÛĒċ-Č î î Û(Č) åÆĦöä Û(Č) ÆŸÖä ÛĮÆÔÒäǦĦŋÁDZ ιÆëÁΣäş ĠëÆÁTä ÿζł3 Ĝłt

المجلد الأول   العدد (١)

مجلة علوم الهندسة والحاسب

(يناير ٢٠٠٨م)   (محرم ١٤٢٩هـ)

المجلة العلمية لجامعة القصيم
(ĞŧÒŢ ĞŸ£)

النشر العلمي والترجمة

بريدة – ص.ب. ٦٦٦٦ – ٥١٤٥٢

بسم الله الرحمن الرحيم

قواعد النشر

أهداف المجلة

تهدف المجلة إلى نشر إنتاج الباحثين من داخل الجامعة وخارجها في جميع تخصصات العلوم الهندسية وعلوم الحاسب، والمجالات الرئيسية التي تشملها المجلة هي:

- الهندسة الكهربائية
- هندسة الحاسب
- الهندسة المدنية
- علوم الحاسب
- الهندسة الميكانيكية
- تكنولوجيا المعلومات
- الهندسة الكيميائية
- نظم المعلومات
- هندسة التعدين والبترول
- العلوم الهندسية الأساسية

لغة المجلة:

تقبل المجلة البحوث باللغة الإنجليزية.

أ) المواد التي تقبلها المجلة للنشر:

١- البحث: وهو عمل أصيل للمؤلف (أو المؤلفين) يضيف جديداً للمعرفة في مجال تخصص (فرع المجلة).

٢- المقالة المرجعية: وتتناول العرض النقدي والتحليلي للبحوث والكتب ونحوها التي سبق نشرها في ميدان معين والرسائل العلمية المتميزة.

٣- المقالة القصيرة (تعليق تقني): مقالة قصيرة تحوي تطبيقاً تقنياً.

٤- الابتكارات العلمية المتميزة وبراءات الاختراع.

٥- المراسلات: وتتناول عرض فكرة أو رأي علمي أو اقتراح بحثي.

٦- انتقادات الكتب

ب) شروط النشر:

١- أن يكون البحث متسماً بالأصالة والابتكار والمنهجية العلمية وسلامة الاتجاه وصحة اللغة وجودة الأسلوب.

٢- أن لا يكون البحث قد سبق نشره أو قدم للنشر لجهة أخرى.

٣- جميع البحوث المقدمة للنشر في المجلة خاضعة للتحكيم.

ج) تعليمات النشر:

عند تقديم البحث للنشر يشترط الآتي:

١- أن يقدم الباحث طلباً بنشر بحثه، ويوضح فيه العنوان الالكتروني للمراسلات.

٢- لا يجوز إعادة نشر أبحاث المجلة في أي مطبوعة أخرى إلا بإذن كتابي من رئيس التحرير.

٣- يرسل الباحث بحثه باللغة الانجليزية عن طريق البريد الالكتروني على العنوان الالكتروني المذكور في فقرة المراسلات، وكذلك ملخص باللغتين العربية والإنجليزية بحيث لا تزيد كلماته عن ٢٠٠ كلمة.

٤- يكتب البحث باستخدام برنامج (Microsoft word) ويستخدم font 12 Times New Roman في كتابة المتن، مع ترك مسافة ونصف بين الأسطر.

٥- يجب ألا يزيد عدد صفحات البحث شاملا الرسومات والجداول عن ٢٠ صفحة حجم A4.

٦- أن يكتب عنوان البحث واسم الباحث وعنوانه ولقبه العلمي والجهة التي يعمل بها على الصفحة الأولى مستقلة.

٧- توضع هوامش كل صفحة أسفلها.

٨- يشار إلى المراجع داخل المتن بالأرقام حسب تسلسل ذكرها وتثبت في فهرس يلحق بآخر البحث.

أ) الدوريات: يشار إليها في المتن بأرقام داخل أقواس مربعة على مستوى السطر. أما في قائمة المراجع فيبدأ المرجع بذكر رقمه داخل قوسين مربعين فاسم عائلة المؤلف ثم الأسماء الأولى أو اختصاراتها فعنوان البحث (بين علامتي تنصيص) فاسم الدورية (تحته خط) فرقم المجلد، فرقم العدد فسنة النشر (بين قوسين) ثم أرقام الصفحات.

مثال: الحميدي، إبراهيم عبدالله. "الهجرة الداخلية في المملكة العربية السعودية حجمها واتجاهاتها." مجلة كلية الآداب، جامعة الملك سعود، م١٦، ع١ (٢٠٠٤م)، ١٠١- ١٥١.

ب) الكتب: يشار إليها في المتن داخل قوسين مربعين مع ذكر الصفحات، مثال ذلك [٨، ص١٦]. أما في قائمة المراجع فيكتب رقم المرجع داخل قوسين مربعين متبوعاً باسم عائلة المؤلف ثم الأسماء الأولى أو اختصاراتها فعنوان الكتاب (تحته خط) فمكان النشر ثم الناشر فسنة النشر.

مثال: اليوسف، صالح سليمان. المشقة تجلب التيسير: دراسة نظرية وتطبيقية، الرياض: المطابع الأهلية للأوفست، ١٩٨٨م.

٩- ترفق جميع الصور والرسوم المتعلقة بالبحث في ملف مستقل.

١٠- ترقم الجداول والرسومات ترقيماً مستقلاً عن ترقيم البحث ويعنون الجدول بعنوان فوق الجدول والرسم بعنوان تحت الرسم.

١١- لا يعاد البحث إلى صاحبه سواء نشر أو لم ينشر.

١٢- يعطى الباحث نسختين من المجلة وعشرين مستلة من بحثه المنشور.

١٣- يلزم الباحث إجراء التعديلات المنصوص عليها في تقارير المحكمين، مع تعليل ما لم يعدل.

١٤- تعبر المواد المنشورة في المجلة عن آراء ونتائج مؤلفيها فقط.

المراسلات

أ.د. محمد عبد السميع عبد الحليم (رئيس هيئة التحرير)

E-mail: quecjour@qec.edu.sa