GEORGIA INSTITUTE OF TECHNOLOGY | OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. ______

Project No. E-21-551 (05424-1A0) | ~~GTRC~~/GIT | DATE 10/22/85

Project Director: W. E. Sayle | School/~~Lab~~ Electrical Engineering

Sponsor: Whirlpool Corporation, Elisha Gray II Research and Engineering Center

Type Agreement: Whirlpool Letter Authorization dated 9/21/85 for EE Fellowship

Award Period: From 9/1/85 To 8/31/88 (Performance) 8/31/86 (Reports)

Sponsor Amount:

	This Change	Total to Date
Estimated:	$ 2,000	$ 2,000
Funded:	$ 2,000	$ 2,000

Cost Sharing Amount: $ None | Cost Sharing No: N/A

Title: Materials Supplement to EE Fellowship

ADMINISTRATIVE DATA

OCA Contact Brian J. Lindberg X4820

1) Sponsor Technical Contact:

Lloyd A. Wampach, Senior VP
Research and Engineering
Whirlpool Corp., Elisha Gray II
Research and Engineering Center
Monte Road
Benton Harbor, MI 49022

2) Sponsor Admin/Contractual Matters:

Dr. Gale Cutler
Whirlpool Corp., Elisha Gray II
Research and Engineering Center
Monte Road
Benton Harbor, MI 49022
(616) 926-5215

Defense Priority Rating: N/A | Military Security Classification: N/A

(or) Company/Industrial Proprietary: N/A

RESTRICTIONS

See Attached N/A Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with All purchases of special items of equipment in excess of $200 each must be approved in writing by Whirlpool, and Whirlpool shall have the option to take Title to such items of equipment at the end of the Fellowship Program.

COMMENTS:

This authorization for materials, special equipment and services is in support of the Area of Study selected for the Fellowship authorized by the Whirlpool letter referenced above.

Follow-on to Project E-21-540.

COPIES TO:

SPONSOR'S I. D. NO. None

Project Director
Research Administrative Network
Research Property Management
Accounting

Procurement/GTRI Supply Services
Research Security Services
Reports Coordinator (OCA)
Research Communications (2)

GTRC
Library
Project File
Other A. Jones

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Date 6/27/89

oject No. E-21-551 Center No. 054251A0

oject Director W. E. Sayle II School/Lab EE

onsor Whirlpool Corporation

ntract/Grant No. Agreement Dated 9/12/86 GTRC ____ GIT XX

ime Contract No. ____

tle Fellowship Agreement

fective Completion Date 8/31/88 (Performance) 12/31/88 (Reports)

oseout Actions Required:

- ___ None
- X Final Invoice or Copy of Last Invoice
- X Final Report of Inventions and/or Subcontracts-Questionnaire sent to P/I
- ___ Government Property Inventory & Related Certificate
- ___ Classified Material Certificate
- ___ Release and Assignment
- ___ Other ____

cludes Subproject No(s). ____

bproject Under Main Project No. ____

ntinues Project No. E-21-540 Continued by Project No. ____

stribution:

- ___ Project Director
- ___ Administrative Network
- ___ Accounting
- ___ Procurement/GTRI Supply Services
- ___ Research Property Management
- ___ Research Security Services
- X Reports Coordinator (OCA)
- ___ GTRC
- X Project File
- 2 Contract Support Division (OCA)
- ___ Other ____

Georgia Institute of Technology

SCHOOL OF ELECTRICAL ENGINEERING
OFFICE OF UNDERGRADUATE AFFAIRS
ATLANTA, GA. 30332-0250
(404) 894-2900

5 June 1989

Mr. Alan Wennerberg
Director of University Relations
Whirlpool Corporation
The Elisha Gray II Research and Engineering Center
Monte Road
Benton Harbor, MI 49022

Dear Alan:

I am pleased to attach a summary of our activity on the 1987-88 Whirlpool Fellowship program.

Our two "former fellows" have moved on to new efforts. Richard Wallace has begun to work under the supervision of one of our new faculty members, Professor David Taylor, in the controls area. Randy Collins defended his dissertation on Monday May 29 and will receive his Ph.D. in electrical engineering on June 10. Randy has accepted a faculty position at Clemson University and will begin this August.

Without the generous support of the Whirlpool Fellowship program, it would have been much more difficult for these and the many other students to become involved in applied research. I am sorry that the programs had to terminate. I hope that in the future Whirlpool will once again be able to support University research.

Sincerely yours,

William Sayle
Professor and Associate Director
for Undergraduate Affairs

copies: Dr. Roger Webb, Acting Director
Dr. Randy Collins
Mr. Richard Wallace
Dr. Dale C. Ray, Assoc Dir for Graduate Affairs
Dr. Helen Grenga, Graduate Studies
Ms. Kathy Knighton, EE

attachments

MEMO 8 May 1989

To: Bill Sayle

From: Richard Wallace

Subject: 1987-88 Whirlpool Activities Report, 4+ months late

Got your memo this morning. I looked for my Whirlpool Report on the flip-top XT compatible (aka Whirlpool Microcomputer), but some of my files were deleted to make room for Power Electronics Lab work, and I guess the report was one of them. I'll try to reproduce it now.

My research topic has changed since the last activity report. While staying in the adjustable-speed drives area, I have shifted my attention away from the linear induction motor and have become more interested in the switched-reluctance motor. This change coincides with my change in thesis advisors; my new advisor is Prof. D. G. Taylor. My thesis topic will be optimization of switched-reluctance motor (SRM) drives for high-performance applications.

The switched-reluctance motor is a doubly-salient machine (with teeth on both the stator and the rotor) which produces torque by sequential excitation of the windings on the stator poles. The torque produced this way will pulsate, unless the pulsations are compensated by high-gain current feedback. Some work on feedback linearization (torque-smoothing) of SRM drives has been published by Prof. Taylor. His work to date has not, however, addressed the design of the magnetic circuit of the SRM, nor the impact of the torque-smoothing control on the power electronics. My research will be in these areas.

So far, I have improved on Prof. Taylor's feedback linearizing control of the SRM by finding an optimal current commutation method. This method minimizes the current ripple and bandwidth in the drive circuit, while forcing the torque ripple to zero. I am presently working on a paper that will document this commutation method and compare the various winding excitation methods that have been used in SRM applications.

After completing the paper, I will begin looking for improvements to the magnetic circuit of the SRM that will enable a feedback linearizing drive circuit to eliminate the torque ripple while allowing even smaller current ripple and bandwidth. Prof. Taylor has obtained MAGNET, a finite-element analysis program that will run on a desktop computer, to be used for the magnetic circuit optimization work. We plan to study variations of the SRM rotor and stator tooth geometries that will give a smoother torque-vs.-rotor angle characteristic.

The overall aim of the SRM research is to find an SRM drive, with improvements to the excitation method and to the magnetic circuit, that will be a viable alternative in high-performance adjustable-speed drive applications that have used DC motors in the past.

Progress Report for
Edward Randolph Collins, Jr.
August 31, 1988

During the period January 1, 1988 to August 31, 1988, significant progress was made toward my Ph.D. My thesis topic involves adjustable speed drives for the single-phase induction motor. Progress was made on three fronts: theory, experimentation, and publications.

The theory of the adjustable speed for an auxiliary winding-equipped single-phase induction motor has been completed. During the period, theory for the torque performance of the single-phase motor supplied by harmonic-producing power supplies was fully developed. Computer simulations based on this theory were run to evaluate the results.

A dynamometer, which includes a single-phase induction motor, an optical torque sensor, a controlled dc machine (generator), and an optically encoding tachometer was constructed on a movable rig. Several single-phase motors were obtained for evaluating the proposed drive using different types of motors. Second generation drive circuitry was constructed to experimentally evaluate the theory as described in the paragraph above and theory developed previously. The experimental drive worked acceptably; findings from the experimentation will be used in the development of a third generation circuit.

My thesis proposal, entitled: "An Adjustable Speed Drive for the Single-phase Induction Motor via Control of the Auxiliary Winding Power Supply," was written and presented. Following an oral examination, the proposal was accepted in full. Additionally, three papers were written and sent out for publication: (1) "Single-phase induction motor speed control by using the auxiliary winding supply," published in the IEEE-IAS Annual Conference Record, (2) "Mathematical models for variable speed ac motors," presented at the NAS-ASUSSR Energy Conservation R&D Symposium, (3) "Torque performance of single-phase induction motors with independently controlled main and auxiliary winding ASD power supplies," submitted for publication in the IEE Proceedings, Part B. These papers summarize the theory and experimental results from my thesis research.

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF ELECTRICAL ENGINEERING
ATLANTA, GEORGIA 30332

ɛLEPHONE: (404) 894- 2946

11 November 1986

Dr. W. Gale Cutler
Staff Vice President
University Relations
The Elisha Gray II
Research and Engineering Center
Monte Road
Benton Harbor, MI 49022

Dear Gale:

I am pleased to submit the reports from Richard Wallace and Randy Collins for the 1985-86 Whirlpool Fellowship Year. You have already received a report from Jim Powell that covered his activities from September 1984 to December 1985.

Richard and Randy have been very active in projects that are of Whirlpool interest. Richard has focused upon the area of magnetic circuitry modeling using numerical techniques. Randy has directed his activities into the design of controllers for synchronous machines. Both of these areas should prove to be important to Whirlpool in its long-range outlook.

I thank you for coming by to visit with Teddy Püttgen and me on 20 October. I am sorry that we do not presently fit into your plans for contractual work but hope that in the future we will be able to get togher on one or more specific projects in the electric machinery area.

Please let me know if you have any questions or desire further information.

Si :erely yours,

..am Sayle II
ɔfessor

WS/el

cc: Sam Pearson (W)
Hans Püttgen (GT)
Dale Ray (GT)
Cindy Meyer (GT)
Demetrius Paris (GT)
Helen Grenga (GT)
Randy Collins (GT)
Richard Wallace (GT)

WHIRPOOL FELLOW REPORT

Edward Randolph Collins

January - August 1986

This report is a summary of my research activities since January, 1986 while on the Whirlpool Fellowship. The current quarter, Fall 1986, basically marks the end of my formal course work toward the Ph.D. degree. I will be taking the Ph.D. Qualifying Exam in the Winter Quarter, 1987 after which I will begin working full-time on my dissertation. My dissertation area is in Power Electronics; specifically I plan to work in the area of solid-state power converter circuit design with application to adjustable speed drives. Over the past months, I have been engaged in research toward the thesis and related areas, conducting laboratory projects and experimental research, literature review, and a computer study. Let me outline further some specific details of my work.

I have done much laboratory work on projects in power electronics for the academic program at Georgia Tech. One project on which I gave considerable effort is a computer-controllable variable voltage dc power supply for 0-120VDC output. This supply will be used in the machinery laboratory as field excitation in large dc and ac machines. The project is fed from the 120VAC line and operates SCR's by phase control to deliver the required output. The input to the supply is a zero current 0 to $\pm$ 10V dc signal and the corresponding 0-120VDC output is switchable by the user to be proportional or inversely proportional to this input signal. The entire circuit is completely isolated and floating, and hence, is completely immune to the possibility of component failure feeding high voltage to the computer or the user. The electronics are operated from a built-in power supply, fed directly from the 120VAC line input. The output may also be manually adjusted, if desired. An ammeter and volt meter give the output conditions, which can presently range up to 15 amperes of continuous current.

Another project I am currently involved with is a multiple output dc to dc power converter circuit operated from a single battery source. This project is to be used by the College of Architecture to provide a portable text-reader for the blind. A "DecTalk" microprocessor-based speech synthesizer and the "Omni-Reader" text encoder require several different (positive and regative) voltage levels to operate. The goal is to have a single rechargable 12V battery supply power to the system. At this time, the prototype power converter circuitry has been assembled on a pc board and is being tested.

I have also engaged in some experimentation in the lab on SCR commutation schemes, especially those in dc to ac inverter bridge configurations. I experimented with some "novel" configurations of commutation circuitry, evaluating them with various loads, voltage levels, and switching frequencies.

In addition to laboratory work, I have begun preliminary research on my Ph.D. thesis. I have been surveying the literature in inverter topologies and designs for single-and three-phase variable voltage and frequency inverters. One subject I have investigated considerably is harmonic content of the output waveforms of these types of inverters. While pursuing this topic, I wrote a Fortran 77 based computer program that will give a complete harmonic analysis of any type of waveform, including the PWM and stair-step types produced by most inverter configurations.

WHIRLPOOL FELLOW REPORT

Richard S. Wallace

September 1985 - August 1986

This is a summary of my activities as a Whirlpool Fellow in Electrical Engineering for the 1985-86 school year at Georgia Tech. I am a Ph.D. student working under Prof. W. E. Sayle. I will take the Qualifying Examination next quarter.

My dissertation topic will be numerical techniques applicable to the analysis of low frequency magnetic circuits and electromechanical structures. The aim of my research will be to improve computer-aided design techniques for energy conversion equipment that includes both electrical and magnetic circuitry.

In the Power Electronics Laboratory, I have directed four undergraduate students as they completed their Senior Design Projects, sponsored by Professor Sayle. Each of these projects included building and testing some type of power conversion circuit for a specific application.

One of these projects was a continuation of the work begun last year on an isolated, SCR-based inverter for supplying an adjustable (0-120) voltage to a rotating machine. The circuit consisted of a control pulse generator and a bridge rectifier with two SCRs. These were realized on separate circuit boards, which were mounted in a metal enclosure with control switches and meters. The design was proved to work on the actual machine load, and will serve as a prototype for several others to be constructed for the laboratory to accompany a new course in Variable Speed Drives.

Another project was a 50-watt inverter driven by a 12-volt battery. The circuit topology was a standard push-pull configuration, in which the switching was accomplished by using a saturable, square-loop type transformer. This circuit, when implemented with a center-tap line voltage transformer normally used for small +/- 12 volt supplies, was very noisy and inefficient. In a subsequent project, a custom-built transformer is being used to improve the efficiency and reduce noise.

The last of these projects was a step-up (boost) type dc-to-dc converter for use in a PROM burner. This circuit featured the MC34063 switching regulator control IC, driving a small (2 ampere) external power BJT. The input was 5 volts, and the output was variable to suit any of several PROM burning intensities.

In each of these projects, it was clear that the optimal design could only be achieved by careful selection of the magnetic energy transfer element. In fact, all the designs had the common flaw that, since the projects had to be completed in just a few weeks each, there was not enough time to design and build the best possible magnetic device for each application.

This year I have also begun a search of the literature that will lead to my selection of a specific dissertation topic. The problem of magnetic circuit design, which came up repeatedly in the Laboratory Projects, has been the principal motivation for my reading so far. The need for better methods of magnetic design should be the central theme of my research in the months to come.

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF ELECTRICAL ENGINEERING
ATLANTA, GEORGIA 30332

:LEPHONE: (404) 894- 2946

27 January 1988

Mr. Alan Wennerberg
Director of University Relations
Whirlpool Corporation
The Elisha Gray II Research and Engineering Center
Monte Road
Benton Harbor, MI 49022

Dear Alan:

Congratulations on your new role as Director of University Relations! Mary Kish gave me the news this afternoon when I called to find out who was succeeding Gale Cutler.

In all of the activities surrounding Gale's retirement, I neglected to submit our Final Report for the 1986-87 Whirlpool Fellowship. I am attaching it to this letter.

One of the requests we had made to Gale concerned the acquisiton of some small single-phase induction motors like you use in your appliances. We need some of these in the 0.5 to 1.5 horsepower range to use as test loads on Randy Collins' solid state motor drives that he is developing. Would you please see what you can do?

Congratulations again on your promotion. I look forward to working with you.

Sincere1-- ours,

William Sayle II
Professor

copies to Sam Pearson, Whirlpool
Randy Collins, Whirlpool Fellow
Richard Wallace, Whirlpool Fellow
Dale C. Ray, Georgia Tech EE
Helen Grenga, Georgia Tech Graduate Studies
Demetrius T. Paris, Georgia Tech EE
Pam Majors, Georgia Tech EE

Whirlpool Fellowship Program

in Electrical Engineering

1986-87 Final Report

Submitted by
William E. Sayle II

School of Electrical Engineering
Georgia Institute of Technolgy
Atlanta, GA 30332-0250

I am pleased to submit the attached "update" reports from Whirlpool Fellows Randy Collins and Richard Wallace. During the 1986-87 academic year both successfully completed the Qualifying Examination phase of their Ph.D. programs. Copies of the major reports that they prepared in conjunction with the research for these examinations were submitted to Whirlpool in May 1987.

E. Randolph Collins, Jr.
Whirlpool Fellowship Activity Report
Georgia Institute of Technology
School of Electrical Engineering
Atlanta, GA 30332-0250

During the Winter Quarter 1987, I took and passed the Ph.D. Qualifying Examination. In the nine months since this examination, I have been heavily involved in research for my dissertation.

My dissertation topic is the development of adjustable speed drives for single-phase ac motors. Obviously, this is a topic of great interest to Whirlpool. I performed extensive literature searches using manual techniques in the the Georgia Tech Library and a state-of-the art database search using the vast resources of TECHDATA. (TECHDATA was available through a special problems course in electrical engineering.)

With these databases I was able to ascertain the achievements to date in the single phase drive area. Surprisingly, the subject has been hardly explored. After exhaustively researching the available materials and gaining a thorough understanding of the theories and issures involved in single phase drives, I have developed several drive schemes for the single phase motor equipped with an auxiliary winding. These analyses have been partially simulated with a computer and have yielded interesting results for control possibilities. To validate these solutions, experimental verification is required.

The experimental verification will use a dynamometer composed of a dc machine, a digitally encoded tachometer, a digitally encoded torque sensor, and the machine under test. The dc machine will be used as a load, configurable to simulate any number of load characteristics. The single phase motor will be removable to facilitate easy testing of several varieties. The Whirlpool Corporation has generously supplied the funds to acquire the torque sensor and the tachometer for the dynamometer. These items have been received and are currently being assembled. Experimental verification will begin soon.

Richard S. Wallace, Jr.
Whirlpool Fellowship Activity Report
Georgia Institute of Technology
School of Electrical Engineering
Atlanta, GA 30332-0250
1986-87

In 1986-87, the Whirlpool Fellowship supported my Ph.D. work in the area of numerical methods applied to the design of magnetics. I have focused on low frequency, kilowatt power level designs, which can be optimized only by careful attention to geometric and material properties. In particular, I have studied the use of the Finite Elements Method (FEM) in analysing these designs.

My Ph.D. Qualifying Examination topic was "The Finite Elements Method in the Design of Linear Induction Machines." Researching and reporting on this topic introduced me to the mathematical basis of the method, and to the literature of its application in magnetics. After passing the Qualifying Examination, I attended a Workshop on Finite Elements for Electrical Engineers at RPI, in Troy, NY. The workshop allowed me hands-on experience with several of the finite element software packages presently on the market.

Recently, Georgia Tech has acquired a FEM package called ANSYS. This package can handle 3-D and nonlinear problems, and contains a routine for optimization of design parameters based on constraints supplied by the user. In a project that is just now beginning, I hope to apply ANSYS to the design of a magnetic transducer for nonintrusive stimulation of specified regions within the human brain, as a tool for locating the sources of some types of mental disorders. This project is directed by Prof. Kent Davey of Georgia Tech's EE School.