3. From the Director, Winnipeg Hydro Department
Report 2001/12/18

Support for Industrial Chair in Power Systems Simulation, University of Manitoba
File H (Vol. 10)

Recommending that the City of Winnipeg support the establishment and operation of an Industrial Chair in Power System Simulation at the University of Manitoba, and that the City of Winnipeg be authorized to enter into a five year agreement to provide financial support for the Industrial Chair in Power System Simulation at the University of Manitoba at the rate of $10,000.00 (PST and GST not applicable) per year beginning in 2002 for a total amount of $50,000.00.

WINNIPEG HYDRO

Re: SUPPORT FOR INDUSTRIAL CHAIR IN POWER SYSTEMS SIMULATION, UNIVERSITY OF MANITOBA

For Submission to: **Executive Policy Committee**

Submitted by: **Director of Winnipeg Hydro**

Report date: **January 8, 2002**

Recommendation(s):

That the City of Winnipeg support the establishment and operation of an Industrial Chair in Power system Simulation at the University of Manitoba, and that the City of Winnipeg be authorized to enter into a five year agreement to provide financial support for the Industrial Chair in Power System Simulation at the University of Manitoba at the rate of $10,000.00 per year beginning in 2002 for a total amount of $50,000.00 (PST and GST not applicable).

REPORT SUMMARY

KEY ISSUES:

Authorize the City of Winnipeg to provide financial support of $10,000.00 (PST and GST not applicable) per year for five years to the University of Manitoba's Research Chair.

IMPLICATIONS OF THE RECOMMENDATIONS:

General implications

- ☐ No
- ☐ For the organization overall and/or for other Departments
- ☐ For the community and/or organizations external to the City
- X Involves a multi-year contract

Comment:

Policy implications

- X No
- ☐ Yes

Comment:

Financial implications

- X Within approved current and/or capital budget
- ☐ Current and/or capital budget adjustment required

Comment:

REPORT

RECOMMENDATION(S):

That the City of Winnipeg support the establishment and operation of an Industrial Chair in Power System Simulation at the University of Manitoba, and that the City of Winnipeg be authorized to enter into a five year agreement to provide financial support for the Industrial Chair in Power System Simulation at the University of Manitoba at the rate of $10,000.00 (PST and GST not applicable) per year beginning in 2002 for a total amount of $50,000.00.

REASON FOR THE REPORT:

The Executive Policy Committee has jurisdiction to approve grants to persons and organizations other than those representing cultural and artistic groups.

HISTORY:

In February 1993, Winnipeg Hydro was authorized to enter into a five-year agreement to provide financial support to the NSERC Industrial Chair at the University of Manitoba at the rate of $7,000.00 per year for a total of $35,000.00. The grant was used by the University to partially fund the salaries for the Senior Chair and three support staff, who provided leadership in directing many graduate students to conduct research in areas of power systems technology. The Industrial Sponsors including Winnipeg Hydro constituted an Advisory Committee that reviewed and assessed the research projects.

DISCUSSION:

The Natural Science and Research Engineering Council (NSERC) continues to encourage programs, which aim to increase the interface between universities and industry. One such program provides partial funding towards establishing and maintaining Industrial Research Chairs within Canadian universities.

NSERC is a Council appointed by the Federal Government and reports to the Minister of State for Science and Technology. They play a major role in approving government grants for post graduate scholarships and industrial research. Approval of the proposed Chair will be evaluated upon the merits of the University's proposal and the interest and commitment of industry. The financial support of industry will be approximately thirty five percent of the cost over a five-year period. A copy of the University's proposal is attached.

NSERC in cooperation with local industry including The City of Winnipeg has previously provided grants for an Industrial Research Chair in Power Systems at the University of Manitoba. Winnipeg Hydro's recent sponsorship to the Chair was $7,000 per year beginning in 1993 for a total amount of $35,000.00. The NSERC Power Systems Chair concluded in 1998.

The University of Manitoba has chosen to continue research in the area of Power Systems. The University has acquired significant expertise in the area of Power Systems Transient Simulation. Also, two of the world's foremost Power System Simulation companies (RTDS Technologies and Manitoba HVDC Research Centre) are located in Winnipeg. The Industrial Research Chair will focus on the

development and use of transient simulation techniques for electric power systems. The University hopes that the NSERC Chair will eventually result in a self-sustaining school of research, which will benefit the University and industry.

Local support is very important to the success of the proposal and includes Manitoba Hydro, Manitoba HVDC Research Centre, RTDS Technologies and Teshmont Consultants.

The University of Manitoba's proposal for contribution support from the various industries is summarized as follows:

Company	Amount	Percentage
NSERC	$1,031,392.00	36.8
University of Manitoba	$ 737,439.00	26.3
Manitoba Hydro	$ 696,393.00	24.9
Man Hydro HVDC Res Cen	$ 200,000.00	7.1
RTDS Technologies	$ 75,000.00	2.7
Winnipeg Hydro	***$ 50,000.00***	***1.8***
Teshmont Consultants	$ 10,000.00	0.4
TOTAL	**$2,800,223.00**	**100.0**

The information was obtained from the University's business proposal that will be submitted to NSERC for consideration.

The University initially requested funding support from the City about a year ago. Although the University was expecting the City to provide support of $150,000 ($30,000/year over five years), Winnipeg Hydro advised the University of Manitoba informally that any grant approved from the City would likely not exceed $10,000 annually for five years ($50,000 total) once the Chair was established.

The Hydro Department did not proceed with a request to authorize funding support until the University provided assurance that they would proceed with the application. Now the City is the last of the prospective sponsors to confirm funding. The University has requested that the City provide confirmation of its financial support as soon as possible.

The Faculty of Engineering at the University has been a valuable resource to the City. They have provided test facilities and expertise, not only in electrical applications, but for civil and mechanical applications as well. One of the strengths of the electrical faculty has been in the area of power systems, and the City as an operator of a power utility has been a beneficiary.
In light of the City's role in the industry through the Hydro Department, an annual contribution of $10,000 for a five-year period is recommended.

Funds are available in the Hydro Department Operating Budget (Account No 40 552101 010103) if the proposal proceeds.

Financial Impact Statement

Date: November 22, 2001

Project Name:

First Year of Program

	2002	2003	2004	2005	2006
Capital					
Capital Expenditures Required					
Less: Existing Budgeted Costs					
Additional Capital Budget Required	$ -	$ -	$ -	$ -	$ -
Funding Sources:					
Debt - Internal					
Debt - External					
Grants (Enter Description Here)					
Reserves, Equity, Surplus					
Other - Enter Description Here					
Total Funding	$ -	$ -	$ -	$ -	$ -
Total Additional Capital Budget Required	$ -				
Total Additional Debt Required	$ -				
Current Expenditures/Revenues					
Direct Costs	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000
Less: Incremental Revenue/Recovery					
Net Cost/(Benefit)	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000
Less: Existing Budget Amounts	10,000	10,000	10,000	10,000	10,000
Net Budget Adjustment Required	$ -	$ -	$ -	$ -	$ -

Additional Comments:

No Financial impact as funds will be budgeted for in the 2002 to 2006 Operating Budgets

Rick Fair
Comptroller

IN PREPARING THE REPORT, THERE WAS CONSULTATION WITH AND CONCURRENCE BY:

The Materials Management Division and the Legal Services Division, who approved the report.

FORM 120
Material Required From Supporting Organizations

THIS REPORT SUBMITTED BY:

Read instructions before completing the form. For Industry/Products and Services Codes, consult the NSERC *Code Book*. For information on the *Access to Information Act* and the *Privacy Act*, consult the NSERC *Researcher's Guide*. If this form is completed and signed by an authorized officer of a supporting organization, this person does not need to sign Form 101.

Family name of applicant Division: Design and Planning Division		Initial(s) of all given names	Personal identification no. (PIN)
Title of proposal Prepared by: Mr. Darryl F. Bukoski, Manager of Design and Planning			
Name of supporting organization Phone No: 986-2307			
Mailing address File name: DP 650-1 ATTACHMENT			
☐ ☐		☐ ☐	
Canadian ownership (in percentage)	Date of incorporation in Canada	Total number of employees in Canada	
Is your organization profit-motivated?		Industry/Products and Services Code	
Types of products sold and/or services offered		Total annual sales for previous year	
		Net profit (loss) for previous year	
Does your organization have an R&D department? ☐ Yes ☐		Has your organization received publicly funded support for R&D directly related to the proposed project? ☐ ☐	
Number of R&D Staff in Canada scientists and technicians	R&D staff with Ph.D.	Annual R&D expenditures (previous/current/next year)	
Signature, name and position of person completing the form			

PROTECTED WHEN COMPLETED

16 Aug. 2001

Given name			
MENZIES	Robert	W.	2792

Industrial Chair in Power Systems Simulation

Name and title of liaison person between organization and applicant

Winnipeg Hydro

Mr. D.F. Bukoski, Manager, Design and Planning

Mailing address (only if different)

1315 Notre Dame Avenue
Winnipeg, MB R3G 3G2

Telephone number	Facsimile number	Telephone number	Facsimile number
(204) 986-2305	(204) 772-3872	(204) 986-2307	

E-mail address

dbukoski@city.winnipeg.mb.ca

Is your organization

☑ the parent company? a subsidiary of? (specify)

Is the applicant or a co-applicant a principal in your organization? Yes ☑ No

Is your organization a Crown corporation? No Yes No

CONTRIBUTIONS TO THE DIRECT COSTS OF RESEARCH	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
a) Cash contribution	$10,000.	$10,000.	$10,000.	$10,000.	$10,000.
b) In-kind contribution					

Natural Sciences and Engineering Research Council of Canada | Conseil de recherches en sciences naturelles et en génie du Canada

FORM 101
Application for a Grant
PART I

Date: 28 August 2001

Family name of applicant	Given name	Initial(s) of all given names	Personal identification no. (PIN)
MENZIES	Robert	W.	2792

Language of application: [x] English [ ] French

Time (in hours per month) to be devoted to the proposed research:

Type of grant applied for: INDUSTRIAL RESEARCH CHAIR

For Strategic Projects, indicate the Target Area and Sub-Area(s), if applicable:

Title of proposal: Industrial Chair in Power Systems Simulation

Write a maximum of ten (10) key words that describe this proposal. Use commas to separate them.

Power Systems Simulation, Deregulation, Reliability, Power Quality, Industrial Collaboration.

Research subject code(s) Primary	Secondary	Area of application code(s) Primary	Secondary
2501	2516	304	513

CERTIFICATION REQUIREMENTS

If this proposal involves any of the following, check the box(es) and submit the protocol to the university certification committee.

Research involving humans [ ] Research involving animals [ ] Research involving biohazards [ ]

Does any phase of the research described in this proposal a) take place outside an office or laboratory, or b) involve an undertaking as described in Part I of Appendix B?

[x] NO [ ] If YES to either question a) or b) - Appendices A and B must be completed

TOTAL AMOUNT REQUESTED FROM NSERC

Year 1	Year 2	Year 3	Year 4	Year 5
$171,825.00	$141,825.00	$136,825.00	$136,825.00	$136,825.00

SIGNATURES (Refer to instructions "What do the signatures on the application mean?")

It is agreed that the general conditions governing grants as outlined in the NSERC *Program Guide for Professors* apply to any grant made pursuant to this application and are hereby accepted by the applicant and the applicant's employing institution.

Applicant

Applicant's department, university, tel. and fax nos., and e-mail

Electrical and Computer Engineering
University of Manitoba
Winnipeg, MB R3T 2N2
(204) 474-8488
(204) 474-7522 Fax

Head of department

Dean of Faculty

President of university (or representative)

The information collected on this form and appendices will be stored in the Personal Information Bank for the appropriate program.

Version française disponible

PROTECTED WHEN COMPLETED

Personal identification no. (PIN)	Family name of applicant
2792	MENZIES

CO-APPLICANTS

I have read the statement "What do the signatures on the application mean?" in the accompanying instructions and agree to it.

PIN, family name and initial(s)	Research time (hours/month)	Organization	Signature

CO-APPLICANTS' ORGANIZATIONS AND/OR SUPPORTING ORGANIZATIONS (if organization different from page 1)

It is agreed that the general conditions governing grants as outlined in the NSERC *Program Guide for Professors*, as well as the statements "What do the signatures on the application mean?" and "Summary of proposal for public release" (on page 3 of this form), in the accompanying instructions, apply to any grant made pursuant to this application and are hereby accepted by the organization.

Family name and given name of signing officer, title of position, and name of organization	Signature

Use additional page(s) if necessary.

Version française disponible

PROTECTED WHEN COMPLETED

Personal identification no. (PIN)	Family name of applicant
2792	MENZIES

SUMMARY OF PROPOSAL FOR PUBLIC RELEASE (Use plain language.) **This plain language summary will be available to the public if your proposal is funded. Although it is not mandatory, you may choose to include your business telephone number and/or your e-mail address to facilitate contact with the public and the media about your research.**

Bus. telephone no. (optional): (204) 474-8488 E-mail address (optional): menzies@ee.umanitoba.ca

The University of Manitoba has acquired significant expertise in the area of Power Systems Transients Stimulation. Also two of the world's foremost Power System Simulation companies (RTDS Technologies and the Manitoba HVDC Res. Centre) are located in Winnipeg. Manitoba Hydro, Electranix Corporation, Teshmont Consultants, and Winnipeg Hydro are amongst several companies that rely on good simulation tools. The right environment therefore exists to build on these strengths and form a strong research initiative for Power Systems Simulation at the University of Manitoba. The University and the Industrial Partners are committed to this venture.

The IRC will focus on the development and use of transient simulation techniques for energy generation, transmission, distribution and utilization. Simulation plays an ever-increasing role in modern power systems due to the introduction of de-regulated markets and a shift away from fossil fuels. Simulation allows one to rapidly evaluate the performance of the system, investigate component stresses and tune controllers; without damage to physical equipment.

It is hoped that the NSERC IRC will eventually result in a self-sustained school of research, which will benefit the University and Canadian Industry. It is also clear that the program will result in a very significant training component.

RESEARCH ACTIVITY SCHEDULE
(Refer to instructions to see if this section applies to your application. Use additional page(s) if necessary.)

Milestone	Description of activities	Anticipated starting date	Anticipated completion date
Hiring of Junior Chairs	- Faculty Search	on approval of project	6 months after approval
Improved Interpolation Algorithms	- Analysis of sources of errors in power calculation arising from interpolation.	6 months	1 year
	- Algorithms for elimination of above errors.	1 year	2.5 years
Improved Cable & Transmission Line Models	- Identification of tools for cable parameter estimation.	start of project	6 months
	- Dependent frequency domain prototyping and validation tools.	6 months	1.5 years
	- Development of accurate cable models in the time domain.	1 year	3 years
	- Advanced modeling techniques.	3 years	5 years

Milestone	Description	Start Date	Completion Date
Models for Electrical Equipment	- Completion of Written Pole Motor Model currently under development.	Start	1.5 years
	- Testing of WP Motor Model with Field Test.	1 month	1 year
	- Improvements to basic model based on testing.	1 year	3 years
	- Further Development of models for other devices (will be based on the status of research).	3 years	5years
Models for Power Electronics Equipment	- Completion of Unified Power Flow Controller Frequency Performance analysis.	6 months	1 year
	- Models for the Interline Power Flow Controller.	1 year	2.5 years
	- Research into System Applications of above devices.	2.5 years	3 years
	- Development of models for new HVDC Topologies.	2.5 years	3.5 years
	- Additional Models (to be determined).	3 years	5 years
Hybrid Applications	- Completion of current work in MATLAB/Simulink and other interfaces.	start	1.5 years
	- Identification of future directions for interfacing.	1.5 years	2 years
	- Advanced development of Hybrid approaches.	2 years	5 years
	- Integration of optimization tools.	1.5 years	2 years
	- Development of Simulation tools which interface to optimization programs.	2 years	3 years
	- Applications to Power Electronic Design and Controller Optimization.	3 years	5 years
Real Time Applications	- Acquisition of equipment.	start	6 months
	- Development of simple prototype platform for Controller design.	6 months	2 years
	- Testing and improvements to design.	2 years	3 years
	- Future Real Time Simulation Design.	3 years	5 years

Personal identification no. (PIN)	Family name of applicant
2792	MENZIES

Before completing this section, **read the instructions** and consult the Financial Administration section in the NSERC *Program Guide for Professors* concerning the eligibility of expenditures for the direct costs of research and the regulations governing the use of grant funds. On separate page(s), supply a detailed explanation, and justification, for your proposed expenditures. **Also explain the relationship or difference between this application and all other research support (held or applied for),** and describe any contributions from other sources (if applicable).

PROPOSED EXPENDITURES FOR DIRECT COSTS OF RESEARCH (Include cash expenditures only)

	Year 1	Year 2	Year 3	Year 4	Year 5
1) Salaries and benefits					
a) Students	$102,000.00	$102,000.00	$102,000.00	$102,000.00	$102,000.00
b) Postdoctoral fellows	69,450.00	69,450.00	69,450.00	69,450.00	69,450.00
c) Technical/professional assistants	44,200.00	44,200.00	44,200.00	44,200.00	44,200.00
d) Other (specify) Office Asst.	12,000.00	12,000.00	12,000.00	12,000.00	12,000.00
2) Equipment or facility					
a) Purchase or rental	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00
b) Operation and maintenance costs	2,000.00	2,000.00	2,000.00	2,000.00	2,000.00
c) User fees					
3) Materials and supplies	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00
4) Travel					
a) Conferences	12,000.00	12,000.00	12,000.00	12,000.00	12,000.00
b) Field work					
c) Collaboration/consultation	90,000.00	90,000.00	90,000.00	90,000.00	90,000.00
5) Dissemination costs					
a) Publication costs	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00
b) Other (specify)					
6) Other (specify)					
a) Major Equipment	90,000.00	30,000.00	20,000.00	20,000.00	20,000.00
b)					
TOTAL PROPOSED EXPENDITURES FOR DIRECT COSTS OF RESEARCH	$343,650.00	$283,650.00	$273,650.00	$273,650.00	$273,650.00
Total cash contribution from industry (if applicable)	$171,825.00	$141,825.00	$136,825.00	$136,825.00	$136,825.00
Total cash contribution from university (if applicable)					
Total cash contribution from other sources (if applicable)					
TOTAL AMOUNT REQUESTED FROM NSERC (transfer to page 1)	$171,825.00	$141,825.00	$136,825.00	$136,825.00	$136,825.00

PROTECTED WHEN COMPLETED

Global Budget for the Research Chair

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
I. **Salary for Chairholders**						
a) Senior Chair, Dr. A.M. Gole						
Salary	100,000	103,000	106,090	109,273	112,551	530,914
Salary Benefits (15.75 %)	15,750	16,223	16,709	17,210	17,727	83,619
Total	115,750	119,223	122,799	126,483	130,278	614,532
b)Junior Chair #1						
Salary	60,000	61,800	63,654	65,564	67,531	318,548
Salary Benefits (15.75 %)	9,450	9,734	10,026	10,326	10,636	50,171
Total	69,450	71,534	73,680	75,890	78,167	368,719
c)Junior Chair #2						
Salary	60,000	61,800	63,654	65,564	67,531	318,548
Salary Benefits (15.75 %)	9,450	9,734	10,026	10,326	10,636	50,171
Total	69,450	71,534	73,680	75,890	78,167	368,719
Total Salary Cost	**254,650**	**262,290**	**270,158**	**278,263**	**286,611**	**1,351,971**
Source of Funds						
a) NSERC	57,875	59,612	61,400	63,241	65,139	307,267
b) Univ of Manitoba	138,900	143,067	147,359	151,780	156,333	737,439
c) Manitoba Hydro	39,875	41,612	43,400	45,241	47,139	217,267
d) Manitoba HVDC Res. Cen.	11,000	11,000	11,000	11,000	11,000	55,000
e) RTDS Technologies	0	0	0	0	0	0
f) Winnipeg Hydro	5,000	5,000	5,000	5,000	5,000	25,000
g) Teshmont Consultants	2,000	2,000	2,000	2,000	2,000	10,000
Total	**254,650**	**262,290**	**270,158**	**278,263**	**286,611**	**1,351,972**
II. **Research Program Cost**						
a) Graduate Students	102,000	102,000	102,000	102,000	102,000	510,000
b) Post Doc. Fellows/Res. Ass.	69,450	69,450	69,450	69,450	69,450	347,250
c) Office Asst. Support	12,000	12,000	12,000	12,000	12,000	60,000
d) Technicians	44,200	44,200	44,200	44,200	44,200	221,000
e) Equipment	5,000	5,000	5,000	5,000	5,000	25,000
f) Maintenance	2,000	2,000	2,000	2,000	2,000	10,000
g) Materials	3,000	3,000	3,000	3,000	3,000	15,000
h) Travel	15,000	15,000	15,000	15,000	15,000	75,000
i) Publication costs	1,000	1,000	1,000	1,000	1,000	5,000
Total Direct Cost of Res. Prog.	**253,650**	**253,650**	**253,650**	**253,650**	**253,650**	**1,268,250**

Global Budget for the Research Chair

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Source of Funds						
a) NSERC	126,825	126,825	126,825	126,825	126,825	634,125
b) Univ of Manitoba						0
c) Manitoba Hydro	92,825	92,825	92,825	92,825	92,825	464,125
d) Manitoba HVDC Res. Cen.	21,000	21,000	21,000	21,000	21,000	105,000
e) RTDS Technologies	10,000	10,000	10,000	10,000	10,000	50,000
f) Winnipeg Hydro	3000	3000	3000	3000	3000	15,000
g) Teshmont Consultants	0	0	0	0	0	0
Total	**253,650**	**253,650**	**253,650**	**253,650**	**253,650**	**1,268,250**
III. **Major Equipment (Excess of $7000/yr) Cost (part of II)**						
a) Additional RTDS Racks	90,000					
b) Upgrade of Computing Equip.		30,000	20,000	20,000	20,000	
Total Equipment Cost	**90,000**	**30,000**	**20,000**	**20,000**	**20,000**	**180,000**
Source of Funds						
a) NSERC	45,000	15,000	10,000	10,000	10,000	90,000
b) Univ of Manitoba						0
c) Manitoba Hydro	15,000					15,000
d) Manitoba HVDC Res. Cen.	8,000	8,000	8,000	8,000	8,000	40,000
e) RTDS Technologies	20,000	5,000				25,000
f) Winnipeg Hydro	2,000	2,000	2,000	2,000	2,000	10,000
g) Teshmont Consultants						0
						0
						0
Total	**90,000**	**30,000**	**20,000**	**20,000**	**20,000**	**180,000**
IV. **Total Direct Cost of Chair (I+II+III)**	**598,300**	**545,940**	**543,808**	**551,913**	**560,261**	**2,800,221**
a) NSERC	229,700	201,437	198,225	200,066	201,964	1,031,392
b) Univ of Manitoba	138,900	143,067	147,359	151,780	156,333	737,439
c) Manitoba Hydro	147,700	134,437	136,225	138,066	139,964	696,392
d) Manitoba HVDC Res. Cen.	40,000	40,000	40,000	40,000	40,000	200,000
e) RTDS Technologies	30,000	15,000	10,000	10,000	10,000	75,000
f) Winnipeg Hydro	10,000	10,000	10,000	10,000	10,000	50,000
g) Teshmont Consultants	2,000	2,000	2,000	2,000	2,000	10,000
Total	**598,300**	**545,940**	**543,808**	**551,913**	**560,261**	**2,800,222**

PROPOSED BUDGET

The proposed operating budget is shown on page 4 with additional pages for the global chair budget. As the junior chairs are not yet hired, and as we are not knowledgeable of their precise funding needs, an individual operating budget for each junior chairholder is not presently included. It is envisaged that the research program will be administered by the senior chair and the research and equipment budget allocated equitably amongst the three chair positions after they are all filled.

In addition to the salary components of the senior and junior chairs (adjusted annually assuming an increase of 3%), funds are required for the salary of a Technologist to assist with the computer and laboratory facilities mentioned below. Also, due to the large scope of the intended research activities, partial assistance for an office assistant ($12000/yr) are also considered necessary.

Due to the nature of simulation work, the program is software intensive and requires computer equipment. Two of the proposed projects (see "Detailed Research Proposal") require a laboratory for the development of real-time simulation tools. A recent NSERC equipment grant ($ 79000, awarded April 2001) is being used for the initial set-up of the laboratory. A component for upgrade, maintenance and supplies is also necessary and has been included in this application (items 2 and 3 on page 4). These amounts are based on the projected cost of replacing one computer per year and associated expenses. Additionally, some of the research projects use the Real Time Digital Simulator from RTDS Technologies. The RTDS equipment purchased earlier is of an earlier generation and must be upgraded to address the needs of the proposed research. The initial equipment cost of $90,000 will be subsidized by a $25000 equipment contribution from RTDS Technologies. Requests for additional RTDS equipment that may be required towards the end of the project will be made through further equipment grant applications. Similarly, an additional equipment cost of $30000 in year 2 and $20000 in subsequent years are requested for the upgrade of the group's computing equipment and software which is necessary for the development of the off-line simulation tools described in the detailed proposal. It is proposed to obtain between 1 to 3 high-end workstations and associated software for approximately $10000 each. The renewal is spread out over the years on purpose, so as to prevent concurrent obsolescence of the computers. Also, some additional equipment may be required to support the research direction of the two junior chairs when they are hired, and is included in the amount.

In addition, an operating research grant for both chairs is necessary for payment to graduate students and post-doctoral fellows. Note that the budget only calls for 6 graduate students (at an average annual salary of $17000) between the senior and junior chairs and essentially forms the core of the graduate researchers. It is expected that the chairholders will apply for additional grants, including NSERC operating grants to supplement the core research, which at the end of the Chair's term will form a self-sustaining research program in power systems simulation. Due to the considerable scope of the proposed research, it is necessary to have two intermediate research positions in the form of post-doctoral fellows or visiting researchers (based on annual salaries of $30000+benefits). These personnel will bring the experience necessary for conducting the research, which is normally not available in the graduate students. Furthermore, a successful research program cannot exist without exchange of ideas and information with other research centres and the post-doctoral visitor component is considered vital to this effort.

Travel costs are estimated at $15000 per year based on five conferences, collaboration visits and field trips at an average cost of $3000/trip. The field trip component is considered important due to the industrial nature of the research activities. Once again, it must be re-iterated, that this only forms the core travel budget and NSERC or other operating grants of the senior and junior shareholders may include additional funds for travel. As the bulk of the publications will be in the IEEE PES Transactions, the publication costs are not likely to be excessive (only extra page charges) and are estimated at $1000/yr.

Proposal for an NSERC Industrial Chair in Power System Simulation

Rationale for Establishing the Chair

This aim of the Chair is to develop a world-class centre for Power Systems Simulation Re- search at the University of Manitoba. Over the years, there have been several successful instances of collaboration in this area between industry and the Department of Electrical Engineering at the University of Manitoba which have led to better utilization of electrical energy as well as in many outstanding commercial products, notable amongst them the PSCAD/EMTDC simulation software and the Real Time Digital Simulator (RTDS). However, these projects have been carried out on a piece-by piece basis either through purely academic research or through projects which were funded by the Sponsors of the proposed Chair. These Sponsors include state of the art electric utilities, two of the world's largest vendors of power systems simulation software and hardware and a leading consultant in the field of dc transmission. Building on this past research experience and these collaborative ties, the opportunity now exists to consolidate this research activity into a strong and sustained research facility at the University of Manitoba. An IRC in Power System Simulation is a logical choice to pursue to establish a world class university Research Centre. This is a field in which Canada leads the world and Winnipeg is in a unique position to provide Canadian solutions to Canadian and international problems. The advantages of this facility to the University and to Canadian industry will be many fold, as described below.

The establishment of such a research facility will permit the University to undertake research in relevant areas that have a direct impact on the competitiveness of industry. A strong and effective Faculty of Engineering requires a well developed partnership with industry. This also results in a source of additional resource to promote the graduate research program. It improves potential employment opportunities for
its graduates and provides industry with a larger pool of highly trained engineers.

One should also look to the needs of the power system utilities; there are a dwindling number of Canadian universities with courses and expertise in power systems. The Europeans and Americans have recognized this problem and have funding initiatives in place to support electrical power systems in their universities. The existence of a world class research facility will attract the best international students and researchers, and foster interest by the undergraduate students in power systems.

The research in the Department got a considerable boost between the period 1988-99 from the NSERC Industrial Research Chair that was held by Prof. P.G. McLaren. The primary emphasis of this chair was in the area of Power Systems Protection and included the design of new methods for fault detection and the development of measurement devices such as optical transducers. This led to spin off products manufactured by Canadian companies and the addition of many software models of protection devices.

The current Chair Proposal is ambitious, and hopes to achieve in the area of power-systems simulation, success similar to that achieved with the above mentioned chair. It proposes to have in place a Senior Chairholder along with two Junior Chairs, a considerable budget component for graduate student and post doctoral researchers, equipment and operating funds for travel and supplies. It is expected that the

chair will create sufficient momentum in power system research so that it is self-sustaining at a world class level, both in terms of personnel as well as laboratory infrastructure. It is expected that the present atmosphere of collaboration with industry partners will be greatly expanded. It is hoped that the competitiveness and world-leadership of Canadian Industry in this area will remain firmly established.

> The University's Engineering Faculty views the area of Power Systems Simulation as one of its key areas and has identified it as a strategic area to be supported over the long term. It realizes that, through the past involvement of its faculty and due to the local presence of several industrial sponsors, it has a potential to have a world class research facility in this area. Research within this area has often originated from the requirements of industry. For example, after the construction of the Nelson River HVDC system, there was a need for the development of simulation tools that allowed for the enhanced representation of thyristors and power-electronic devices as well as their controls. Improved modeling techniques were developed which culminated with the EMTDC (now PSCAD/EMTDC) transients simulation program, now supported by the Manitoba HVDC Research Centre. Similarly, the Department has been actively involved in the development of the Real Time Digital Simulator (RTDS) currently being manufactured by RTDS Technologies of Winnipeg under license from the Manitoba HVDC Research Centre.

Similarly the sponsors too are committed to long term cooperation. Their expectations from the Chair's activities are as summarized as follows:

- Availability of a core of research personnel, which through collaborative research initiatives, will precipitate in the development of improved software and hardware tools which will increase the sponsors' competitiveness
- The opportunity to use the simulation research to improve the efficiency and cost of electric power generation and utilization.
- The possibility of using simulation tools to investigate new topologies for Power Electronic Equipment in Power Networks
- The opportunity for continuing education through the seminars and courses which will be offered by the University personnel
- The availability of highly trained professionals for future potential employment.

Nature of the Positions

As mentioned earlier, the proposal calls for one Senior Chair and Two Junior Chairs. The Senior Chair will be a Tenured Full Professor and Dr. Ani Gole has been identified as the incumbent. The Junior Chairs will be at the Assistant Professor rank and have not yet been selected.

The Senior Chair will have no formal teaching or administrative responsibilities within the department. His primary responsibility will be to oversee the Chair Research and to supervise the research of his graduate students. However, Dr. Gole does intend to teach one graduate course per year during the term the chair.

The Junior Chair incumbents will be offered tenure-stream appointments at the Assistant Professor level. Standard university policies on advertising and selection will be followed, with the exception that the search committee will be augmented with representatives of the industrial sponsors. Both these Junior positions will be expected to assume normal teaching and administrative loads within the Department. If the selected candidates have no prior teaching experience, the Department's policy is to partially or completely relieve them of the teaching load in the first year so that they are in a position to get their research started.

The Senior Chair Candidate

In order to carry out the proposed scope of work, the person selected for the Senior Chair should have internationally recognized expertise in the area of power systems transients simulation. As the working philosophy of the group is to have very close interaction with industry, the candidate should also be sensitive to the needs of the industrial collaborators, preferably having worked closely with industry in the past. As the proposed activities will require the supervision of several researchers and a technologist, experience of supervising a research program is important. The nominee, Dr. Gole satisfies all the above requirements. He has been with the Department of Electrical and Computer Engineering for over eighteen years and currently holds the rank of Professor. During this period 8 Ph.D. and over 20 M.Sc. graduates have conducted their research under his supervision.

Dr. Gole has an established record of research in the power systems simulation area, particularly in the area of modeling of power electronics, electrical machines and numerical algorithms. Dr. Ani Gole together with Dennis Woodford and Garth Irwin of Electranix, Winnipeg, led the development team for the PSCAD/EMTDC power system simulation program and were the principal developers. Dr. Ani Gole and Dennis Woodford were co-authors on the original publication on this program. Dr. Gole has over 85 transactions and conference publications and is the principal editor of a book (IEEE Special Publication) on transient simulation techniques. Dr. Gole has had industrial experience with Hydro Quebec, Manitoba Hydro and the Manitoba HVDC Research Centre totaling approximately seven years. Dr. Gole is an active member of several working groups of the IEEE and CIGRE and is currently the Vice-chair of IEEE PES Working Group 15.08, "Modeling and Analysis of System Transients Using Digital Programs".

Dr. Gole has been a consultant to several industrial clients; SIEMENS AG, Erlangen; Brandt Consultants, Winnipeg; Xerox Corporation, N.Y.; RTDS Technologies, Winnipeg, in addition to the three mentioned earlier. He has conducted advanced simulation workshops at KEMA, Netherlands; FURNAS, Brazil; NESA, Denmark; the Korean Electric Power Research Centre; Hitachi, Japan and Manitoba Hydro, Winnipeg. He is also on a continuing basis, an invited lecturer at the ABB T&D University in Ludvika, Sweden.

In addition to researching modeling and simulation techniques, Dr. Gole continues to be involved in several key initiatives in simulation technology, particularly looking at hybrid approaches where the simulation is an embedded tool in other applications. In light of the above points, it is a logical choice to nominate Dr. Gole for the IRC Senior Chair.

Junior Chair Candidate Requirements

The rationale for the suggested research areas for the junior chairs is that a strong and sustained research activity in simulation cannot be conducted in a vacuum. Simulation involves the modeling of real physical phenomena and collaboration with experts in the area to which simulation is applied is crucial. Similarly, simulation is a computer-intensive activity and there is a great benefit from the involvement of an expert in a suitable computer field.

It is therefore proposed that the field of specialization of one of the Junior Chairs be in the application area of deregulation, reliability and power quality, with the other Junior Chair in an allied area such as materials for optical transducers, superconductivity, electromagnetics, control theory, or software engineering. This latter candidate should be willing to do research on power systems applications of their primary expertise. Such expertise in a basic area should lead to fundamental advances in the field of power systems. For example, expertise in electromagnetics allows for improved modeling of electric machines, arcs and transmission lines. Likewise, expertise in control systems could lead either to better ideas for control modeling or even to fundamental improvements to the simulation algorithm itself. Expertise in software engineering could address problems such as expandable and maintainable simulation software and so on.

Use of Senior Chair's Freed Up Salary

The University will use all of the freed-up salary funds of the Senior Chair to support the salary costs of the Chairholders. This will allow more of the industrial funding to go directly to the support of the research program.

Position of the Chair within the Engineering Faculty and Potential Interactions.

The Faculty of Engineering has established a number of initiatives for furthering excellence in Research. Currently there are two NSERC Chairs, one an IRC in the area of Aerospace Materials and the other in Design Engineering.

The Faculty is the headquarters of a National Centre of Excellence in Intelligent Sensing for Innovative Structures (ISIS) and participates in three National Networks of Centres of Excellence in microelectronics, telecommunications, and robotics. The Faculty also participates with TRLabs in research on telecommunications. In response to advances in technology, the Faculty of Engineering uses state-of- the-art equipment for both teaching and research.

One notable facility is the Antenna Laboratory, where antennas for portable communications devices are tested in a joint venture with industry. Another major installation is the Structural Engineering and Construction Research and Development Facility.

The NSERC IRC in Power Systems Simulation will form an additional component of this Research Initiative. Strategically, the Faculty seeks to extend areas in which it has established expertise and for

which there is considerable industrial support. The Power Systems Simulation Area satisfies both these criteria.

Due to the Applied and Interdisciplinary nature of Power Systems Simulation, it is expected that the Chair will generate collaborations within and outside the Electrical Engineering Department. Indeed, one extremely significant strength of this faculty is the ability of members to work together across disciplines, for example collaborations between the areas of VLSI Design, optoelectronics and signal processing, and the power systems group. Power systems has become a suitable test bed for many of the new information technologies, such as Digital Signal Processing chips, artificial neural networks, and genetic algorithms.

These interactions have been clarified later in expanded form in the Detailed Chair Proposal. Within the Department, interaction with other Power Systems Professors is necessary to find suitable application areas for the Simulation Research. Also, research collaborations with other experts such as material scientists and electromagnetic scientists is envisaged for determination of the physical characteristic of the phenomena or equipment being simulated. Such collaborations are also expected to take place between the Chair and Professors in Mechanical and Civil Engineering Departments involved with prime mover dynamics. Similarly, outside the Department, collaborations with members of the Computer Science Department are possible for the investigation of improved programming methods.

Indeed one of the Junior Chairs expected to be in an interdisciplinary area so that such collaborations can be further pursued. The fact that this Junior Chair's research effort will directly be in the Power Systems Simulation area will make such interaction far more productive.

Interactions with the Sponsoring Industries are described in the above section on "Rationale.."

Research Facilities and Infrastructure to be Provided by the University.

The Faculty of Engineering at the University of Manitoba has been in existence for over 85 years and is the only CEAB accredited degree granting institution in the province. Electrical Engineering has been an important component of the curriculum right from the beginning. The department has approximately 28 full time academic staff members, five of which can be considered to work in the area of Power Systems Engineering. The Department is committed to maintaining this level of support for the Power Systems group and supporting such initiatives as this IRC to further strengthen the research area. The University currently makes available space for the simulation laboratory. Improved facilities for the laboratory, including a software development laboratory and a hardware laboratory are included in the Faculty's plan for the new Engineering Building to be constructed between 2002-4. The University is also committed to using the funds relieved by the Senior Chair Incumbent for salary support for the Junior Chair Personnel. Similarly, additional partial support for the technologist and administrative assistant are guaranteed by the University.

Research Capacity

In the power systems area, the Department has a well developed Digital Signal Processing Laboratory for Power Systems applications. There is also a fairly comprehensive computation facility (originally made available through a 1994 NSERC Equipment Grant) and a small state-of-the-art Real Time Digital Simulator (RTDS) (also made available through an earlier NSERC Equipment Grant). The Department has a well equipped electrical machines laboratory with facilities to conduct experimental work in power electronics. Finally there is a well established High Voltage Laboratory with a 2 MV impulse generator.

It is envisaged that the Chair will directly bring additional facilities into the Department in the form of computer simulation equipment, real-time control and simulation hardware. The Department has traditionally been very open to the sharing of equipment between groups, so these facilities would also enhance the research in other areas of modeling and in real-time control systems research. Indirectly, as the use of simulation is expected to spawn concurrent development in allied areas such as power electronics, it is expected that, through collaboration with the Chair, the strong Power-Systems Electronics group will also end up with improved facilities through their own research endeavors.

Also as mentioned earlier, there are five faculty members whose research field is power systems engineering. As the incumbent is an internal candidate, the hiring of the Junior Chairs will lead to at least one additional position in the area of power systems, and in particular, increase the number of Professors involved in the Power Systems Simulation area. It will also raise the level of activity in Simulations research within the department and lead to additional interdisciplinary liaisons within the Faculty.

Intellectual Property

Intellectual property matters will be covered in a Research Chair agreement based on the University of Manitoba proforma chair agreement to be executed between the parties upon receipt of award.

Incrementality

The Power Systems Group already enjoys a high level of interaction with industry. Significant advances have resulted in the area of Power Systems Transients Simulation as a result of this interaction. However, the projects undertaken have been conducted on a one-by one basis. Similarly, the facilities have emerged in a somewhat uncoordinated manner. The Chair provides the opportunity to create excellent facilities in a comprehensive manner. It also calls for the establishment of a core group of personnel, which will focus on power system simulation topics. This approach will have a two-fold advantage. Firstly, because of the availability of the core funding, research projects with long-term objectives could be undertaken. This was difficult with the piecemeal project-by project approach that has been utilized so far. That the sponsors see a value in this long-term research is clear, as they are willing to put up their part of the funding. Secondly, due to the creation of a critical mass of highly trained power systems simulation specialists, several additional research projects of industrial significance could be carried out than is currently possible.

Detailed Research Proposal

Synopsis:

The Industrial Research Chair will focus on the development and use of transient simulation techniques for energy generation, transmission and distribution equipment. Changes in the philosophy of operating power systems, brought about due to introduction of de-regulation and a shift away from dependence on large fossil-fuel based generation, has led to an increased demand for simulation software and hardware. The inclusion of power-electronics based equipment in the network makes the task of simulation more difficult due to the inclusion of several additional semiconductor switches. Improvements in the basic simulation algorithm are therefore required so as to increase simulation speed without a corresponding loss of accuracy. One of the principal areas of research will include the investigation of such algorithms. Similarly, improved modeling for various other devices such as machines and transmission lines will be conducted.

Another major activity of the Chair will include the modeling and simulation of new and existing power electronic equipment such Flexible Ac Transmission Systems-*FACTS* and advanced HVDC transmission. The emphasis will be on interaction with the ac network. Such devices allow more effective control of the power flow in a network and offer exciting possibilities for energy transactions in a deregulated environment. Three of the industrial sponsors are utilities or consultants and the results from such research will directly benefit them through increased understanding of the phenomena. The research will also allow for the informed selection of future transmission options as well as efficient use of existing apparatus.

The third major research direction will investigate hybrid approaches towards simulation. The simulation is conducted by combining the electromagnetic simulation tool with other programs; with each software component designed to satisfy a certain protocol that makes it possible for these programs to be interfaced easily. This synergistic approach greatly enhances the power available to the simulation engineer.

The fourth major research direction concerns real-time simulation and related activities. Improved algorithms for real-time simulation and better use of real-time simulators by adding features such as optimization will be investigated. Another attractive topic in this area is to use off-line-simulation software to directly produce real-time Digital Signal Processor code for implementation in a physical power-electronic apparatus. It is hoped that this approach will significantly reduce the design cycle for actual controls for power electronics equipment.

It is expected that these activities will be carried out in close collaboration with the industrial sponsors. As two of the sponsors are amongst the world's largest manufacturers of power-system transient simulation software and hardware, it is hoped that the fruits of the research will be assimilated into their products. In addition, the publication of the research in learned journals and conferences will also benefit other Canadian manufacturers of simulation tools; a field in which Canadian industry is preeminent worldwide. Similarly the development and studies using the advanced power-electronic system models should also benefit the local sponsors as well as Canadian and international industry at large.

The candidate Dr. Ani Gole has considerable experience in the design and use of simulation tools. Together with Dennis Woodford and Garth Irwin, he led the original development team for the widely used PSCAD/EMTDC program. He has over 85 publications in the area including one book for which he was principal editor [1]. Two of these publications were awarded prizes by the IEEE power engineering society. It is expected that under his leadership as the NSERC Industrial Chair, the University of Manitoba will build on its current strength and achieve the critical mass to be a key centre for power systems transients simulation technology; and an important resource for the Canadian Simulation Industry.

Background

As indicated above, simulation is playing an ever increasing role in modern power systems. Transients simulation in particular allows one to estimate the stresses on equipment such as transformers, machines and transmission lines; allows for the proper settings of protection equipment and the tuning of controllers. These studies are carried out without damage to actual equipment and in a very short time. There are several recent advances in transient simulation technology and are listed below:

i) *Advances in basic algorithms:* Most modern power system transient simulation programs are based on the trapezoidal-rule admittance matrix formulation originated by Prof. Dommel [2] over thirty years ago. Several recent improvements have been made to the basic solution algorithm for speedier and more accurate solution. The use of interpolated switching techniques was initiated by Kulicke et al in Germany [3,4], and has been further improved by our group in Manitoba[5]. These algorithms are now available in commercial software packages such as NETOMAC (from Siemens) and PSCAD/EMTDC (Manitoba Hvdc Res. Centre).There are also some initiatives towards the construction of prototyping tools[6] so that new algorithms can be studied in a stand-alone fashion, the need for a commercial simulation package.

ii) Advances in Models: The use of new transmission line topologies such as compact lines and the ever increasing use of cables for transmission and distribution requires new formulations which more correctly account for the skin effect of the conductor and the ground and also for proximity effects. Such formulations are being pursued at several locations around the world [7,8,9]. Similar advances are being carried out in the models for transformers, machines and other power equipment.

iii) Advances in Power Electronic Systems Simulation: Simulation programs are being used to build "digital prototypes" of several new power electronic topologies and their control systems [10,11]. There is a requirement for studying the impact of such equipment when embedded in large power networks. The issues are not only the dynamic impact of the electronics and the ac network on each other, but also the investigation of harmonic penetration and other power quality issues related to the network.

iv) Non-conventional Software Approaches: One approach to transients simulation is to use a commercially available mathematics and control modeling tool such as MATLAB/SIMULINK. A group in Quebec [12] has developed such tools which are now available commercially as the MAT- LAB Power Systems Blockset. The advantage of this approach is that the entire body of models from the host program (MATLAB), immediately become available to the power-systems model. Our group in Manitoba is also investigating the "Open Systems" approach which allows one to interface to an emtp-type program, several different types of software [13].

iv) Real-Time Applications: Several different commercial platforms [14,15,16] have been developed for Real-time simulation. Such simulation tools are necessary for testing prototype controls

for use with FACTS and HVDC devices as well as for testing relays. In a real-time simulation, each time-step in the digital simulation is synchronized with a real-world clock, so that the actual time required for the simulated events is identical to the time required for the same process in the real world. The most widely used amongst these is the *RTDS* from one of the sponsors (RTDS Technologies of Winnipeg). Similarly efforts are under way to reduce development time for real controls by directly converting the control systems part of a simulation to assembly-level code that runs on the Digital Signal Processor based control boards of the physical FACTS device.

The current program of research will be based on several important accomplishments achieved by Dr. Gole over his twenty years of experience in this field. When Dennis Woodford, then at Manitoba Hydro, started the development of the PSCAD/EMTDC simulation program [17], Dr. Gole joined him as his principal co-developer. Dr. Gole has been responsible for the incorporation of the electrical machines and power-electronics controls components of this program. This program has been acquired by the Manitoba HVDC Research Centre and is the most widely used commercially available package for the study of HVDC and FACTS based power Systems. Several of these ideas have also been introduced into the real-time Digital Simulator [14] from RTDS Technologies. Dr. Gole's research work includes several additional aspects of this program, such as the incorporation of improved interpolation techniques, improved building blocks for power-electronic controls and non-conventional machines. More recently, Dr. Gole's research has focused on "open-Systems" approaches to simulation. The aim of this activity is to structure electromagnetic transients programs in such a way so that they can be interfaced to other design tools. Dr. Gole has also demonstrated the use of these simulation tools for the study of emerging FACTS and HVDC electronic topologies as well as for other power-systems phenomena [11,18].

Proposed Research

The topics presented below are some of the important areas that will be investigated:

1. Improvements to the basic simulation algorithm: The trapezoidal rule based algorithm used in several electromagnetic transient programs [2] (referred to as emtp-type programs) has been time tested and found to be robust. Nevertheless, the algorithm is continually being improved. The inclusion of numerical interpolation originally introduced by Kulicke et. al. [3,4], and later modified by the Manitoba team has made the algorithm suitable for simulating large scale power-electronic systems embedded in large power networks [5,19]. This innovation overcomes the problems of current-chopping and firing angle jitter associated with discrete time-step simulation algorithms. For the simulation of non-linear systems, an iterative solution is often required. We propose to introduce in the future, a single algorithm that incorporates the interpolation algorithm into the iterative procedure. This will permit users to interface complex non-linear models such as power-electronic device characteristics into emtp-type formulations.

2. Development of Improved Transmission Line and cable Models: Present day emtp-type models for transmission lines and cables need to be improved so that their frequency response is accurate all the way from dc to a few megahertz. This is particularly important in the case of investigations of transients on dc transmission lines. We propose to develop such models based on the recently reported advances in the techniques for frequency-domain transfer-function fitting and frequency-dependent equivalents. Similarly, better techniques for the calculation of cable parameters for different core geometries are also an area of considerable interest. It is

proposed to utilize a numerical finite-element analysis approach to address this problem because of the difficulty with a purely analytical formulation.

3. Development of Models for Electric Equipment: The continuing developments in the field of power systems means that models for the new devices need to be introduced. For example, the group is currently developing models for the written-pole motor [20], a three-phase motor capable of representing internal faults and models for disconnect switches. Similarly, models for various protective devices and current and potential transformers have also been developed within the group [21]. Several other device models would also be considered in the future.

   One of the requirements of model development is that of validation. Materials and supplies for the existing departmental laboratories would be required for such efforts. In addition, the sponsors' facilities could also be used for such verification. Manitoba Hydro has generously provided such facilities in the past.

4. Power Electronics Modeling: This activity is a key part of the groups' efforts and is an area in which we have been accorded international recognition. There are two parts to this activity, the first at the algorithmic level, where we propose to build more accurate representations of the semiconductor switch. Industry has identified that at least a limited representation of the device characteristic is important for the simulation of HVDC converters to ascertain the levels of power loss during operation and for the design of device-protective equipment.

   On the second level, we intend to investigate various topologies and control algorithms for power-electronic devices in power systems. At present the group is investigating the operation and control of various voltage sourced converter (VSC) topologies, including devices such as the Multi-terminal Unified Power Flow Controller [22], as well as new topologies for HVDC converters such as series capacitor commutation and Voltage Source DC Transmission [18,11].

5. Hybrid (Open-System) Applications: The basic emtp-type algorithm has been successfully interfaced by researchers in our group with other units of software or hardware. This includes an interface to a totally different type of simulation algorithm, such as a state variable solution based model for a static VAR compensator, or an interface to a different program such as a stability program or MATLAB/SIMULINK [13]. This approach allows one to take advantage of the rapid speed of the trapezoidal solution for the transient network solution, with the specific strengths in the interfaced program. For example the "canned" packages available in MATLAB, say for a Fuzzy logic controller can instantly be applied to the control of an HVDC converter model available in PSCAD/EMTDC. The interfacing is carried out using drag and drop graphical icons on a drawing palette that makes the procedure rather straightforward. It is envisaged that the MATLAB interface will be further improved to address issues such as simultaneous initialization in both programs.

   Similarly, in collaboration with SIEMENS of Erlangen, Germany and Brandt Consultants of Winnipeg, MB, we designed an interface between the manufacturer's Digital Signal Processor (DSP) based controller boards and the emtp-type program PSCAD/EMTDC [23]. In this way, one can design the controller to control the model of the large electrical network, and once a satisfactory design is developed in the simulation, it can directly be loaded to the controller

board for instant application in the field. Prototype tests on the system show great promise in this approach.

In a similar manner, we also aim to investigate other interfaces between transient simulation programs and other units of hardware and software.

6. Real-Time Simulation and Allied Activities: The Power Systems Group has played a pivotal role in the development of the original Real Time Digital Simulator (RTDS) which to my knowledge is the first Supercomputer ever built in Canada.

We continue to support RTDS development through the development of new models such as those for power-system protection equipment [14] and exact HVDC Controls. This activity is expected to expand over the duration of the chair. We also expect to investigate new uses for the RTDS. This would include using it to use it in an optimization loop, where the network solution yields the objective function to be optimized. This would greatly increase the use of the RTDS for design.

Recently, the group has been responsible for a novel Real-time playback system, in which PSCAD/EMTDC generated simulation results can be played out in a comprehensive manner and used for the testing of physical relay equipment [24].

Additional projects currently undertaken include an interface between PSCAD and a DSP-based hardware controller for the University of Manitoba HVDC (Analog) Simulator. Here, the desired controller is developed on the PSCAD graphical palette and converted to code that runs on a DSP (Digital Signal Processor) board. The DSP board then issues firing pulses and other necessary control signals to the simulators' hardware components. An NSERC Equipment grant was applied for and awarded in 2001 for the purchase of the preliminary set of tools required for this effort.

Similarly, another project being actively pursued is that for the implementation of a High-Speed Stability (HSST) Program. The aim is to model very large networks using a stability framework (where the mechanical equations are modeled in full detail, and the electrical network is represented in phasor form). The highly-parallel algorithm can either be implemented either on an RTDS-type specialized computer or on a distributed computer network. Such a program would be valuable for rapid contingency identification and the generation of other load-flow or stability information required in a utility's Load Despatch Centre.

Expected Accomplishments:

Some of the major accomplishments, which can be expected in the five years of the chair include the following:

i) Improved simulation algorithms for handling power-electronic devices.
ii) Models for electric machinery and other power system equipment
iii) Advances in the parameter estimation and simulation of transmission lines and cables.
iv) Methods and guidelines for combining transients simulation with other software tools. It is also expected that at least one of the sponsors will directly incorporate these into their products.

v) Investigation of and new topologies for FACTS equipment and the design of efficient control methods, through the use of transients simulation as a tool.
vi) New uses for Real-time as well as off-line simulation tools, such as in optimization and rapid design methods for physical control systems.

By its very nature, research is unpredictable. The most important outcomes arise from a blend of ideas generated by previous work, new inspiration and accidental events. It is therefore almost certain that when the list of accomplishments is tabulated at the end of the period, it will look different from the above list. The most valuable fruits may very well be unforeseen at this stage.

Proposed Collaborations
The area of Power Systems Transient Simulation is highly applied. It borrows many ideas from circuit theory, electromagnetic theory, power systems and computers. Similarly, a researcher in this area must also be very conversant with the potential application areas in power systems. The Chair therefore intends to rely on collaborations with colleagues from his University as well as with those from the sponsoring organizations.

Prof. Dennis Woodford (CEO, Electranix Corporation and Adjunct Professor), and his colleague Garth Erwin will continue to work closely with the Chair on all aspects of the basic simulation algorithm as well as on the development of other models and application of simulation in the area of distributed generation. In the past, Prof. Dereck Meek of the Dept. of Computer Science has contributed to the area of numerical algorithms for power systems simulation. This collaboration is also expected to be expanded.

I intend to work with Profs. J. Lovetri and E. Bridges in the area of transmission line modeling; leveraging on their research expertise in electromagnetic theory, transmission lines and computation techniques. Similarly, I expect to continue to collaborate with Dr. W. Lehn one of whose speciality is Modern Control Theory. His ideas are useful in the development of control algorithms for FACTS devices as well as for basic simulation algorithms.

I also intend to work closely with my colleagues in the Power Systems area, Dr. U. Annakkkage and Dr. R. Menzies. Dr. Annakkage specializes in power system operation, security analysis, economics and optimization. His input is valuable to the study of new FACTS topologies for secure and economic interconnections. I already work very closely with him. Dr. Menzies is a specialist in Power Electronics and Machines and has also been involved with PSCAD/EMTDC development for a long time. His knowledge of machine structure and operation is invaluable for developing comprehensive models. His input is also vital for laboratory corroboration of the developed models. Additionally, he constructs several physical models of FACTS and other power electronic circuits, which complements the numerical simulation studies in a major way. Similarly, the research area of the Junior Chairs will either directly support or complement the research direction.

I intend to work very closely with several of the Sponsoring Organizations. At the Manitoba HVDC Research Centre, I expect to collaborate with R. Wachal on Real-time control and real-time playback technologies. Similarly Dr. R. Jayasinghe, Dr. D. Muthumuni, J. Nordstrom, R. Wachal and P. Buchanan will collaborate on all aspects of improving the simulation tools and models. The PSCAD/EMTDC is expected to benefit directly as a result of this collaboration.

A similar link also exists between the University and RTDS Technologies. Dr. T. Maguire (one of the principals of the company) is an Adjunct Professor at the University and works closely with us on algorithms and machines. It is hoped that the activities of the Research Chair will enable this company to improve its product and also to look for new application areas.

The largest benefit to the other sponsoring organizations (Manitoba Hydro, Teshmont Consultants and Winnipeg Hydro) will accrue from investigations into new power-electronics based apparatus. A large component of Manitoba Hydro's power is generated in the extreme North of the province and exported into the United States and neighbouring provinces (approx. $480 Million in 2001). For this reason, Manitoba Hydro has been a leader in the use of High Voltage DC Transmission technology and this trend is expected to continue. It is also the organization in which the PSCAD/EMTDC tool was originated. The simulation tools, which are developed will directly benefit Manitoba Hydro in these efforts. Several personnel from Hydro act as liaisons between Hydro and the University; Dr. D. Jacobson, Prof. D.G. Chapman (Adjunct), Dr. H. Turanli and Mr. J.B. Davies have been closely associated with my research in the past and will continue to collaborate on all aspects of simulation. Similarly, Teshmont Consultants is a major International Consultant for HVDC and FACTS Apparatus and a strong user of PSCAD/EMTDC. There is an ongoing need for comprehensive studies of FACTS apparatus and their frequency response characteristics. It is expected that the Chair's work will closely benefit this activity. Similarly, Winnipeg Hydro will benefit from applying simulation studies to generation and distribution problems within their organization. Power electronics equipment (at the customer as well as utility side) is forming an ever-increasing component of the distribution network, and simulation provides an effective study tool.

An additional contribution to the Sponsoring Organizations and to the Canadian Power Systems industry will be the training of Highly Qualified Personnel which will be available for employment all across the country in the highly strategic area of Energy. Similarly, the Chair aims to publish key results in journals and conference proceedings thereby benefiting the entire power community.

Research Management

The primary responsibility for the research direction will reside with the Chair. The Chair will interface directly with the junior chairs, graduate researchers, post-doctoral fellows and other research staff. For good research, it is necessary for the researchers to have a large measure of freedom for action, and the Chair will attempt to foster an atmosphere of collegiality rather than establish a firm chain of command. However, it is hoped that some informal groups will emerge based on the interests being pursued.

The sponsors will provide input to the direction of research through an Advisory Group. It is expected that this Advisory group will meet twice per year to review the direction of research and discuss any results that may have accumulated over the previous period. The purpose of the Advisory Group is to provide general guidance; the principal direction of research being the responsibility of the Chairholder. It is hoped that matters of interest to the Sponsors can be brought to the Chair's attention through such meetings.

The resources directly available through the NSERC IRC will be used for the core program of activities and for seed funding. It is expected that other grants and contracts will be applied for to supplement the activities. This is particularly important when some of the work is directly targeted for one of the Sponsor's commercial products. In such an instance, a separate contract will be initiated following the University's policies on contracts and intellectual property.

The University's central accounting structure for research grants and contracts will be utilized as in the case of any other research grants; with all the conditions thereto appertaining. Local administration of correspondence, preparation of purchase orders and pay forms and purchase of incidental equipment and consumable supplies will be handled by the secretary and technologist assigned to the Chairholder.

Training of Highly Qualified Personnel

The core program of the Chair expects to fund 5-7 graduate students and 2 post-doctoral fellows/ Research Assistants on a continuing basis. It is hoped that additional grants and contracts will be applied for by the Senior and Junior Chair which will generate additional research positions. It is expected that the graduate research positions will be split evenly between Masters and Doctoral Students. Collectively, these students will have acquired skills in electrical energy systems; the theory and practice of transients simulation; computer programming and usage; and the construction and programming of Digital Signal Processor Based Control platforms. Judging from past experience, these highly qualified students are employable by the Sponsors and other Canadian industry, in the energy sector as well as in other electrical and computer engineering sectors. It is also expected that some of the Ph.D. graduates and Post-Doctoral Fellows will obtain employment in Canadian Universities and further train other personnel.

A significant number of the Sponsors' employees pursue part-time graduate programs at the University and some may work directly with the Chair. Also, a large portion of the Chair's research will be carried out in collaboration with the Sponsors and thereby add to the training component. It is also planned to hold short courses on advanced topics which should be well attended by the Sponsors' engineering personnel.

References

[1] A.M. Gole (Principal Editor), J. Martinez Velasco and A.J.F. Keri, "Modeling and Analysis of System Transients Using Digital Programs", IEEE Special Publication, IEEE Catalog No. 99TP 133-0, Piscataway, N.J., January 1999.

[2]Dommel H.W., "Digital Computer Solution of Electromagnetic Transients in Single- and Multi-Phase Networks", IEEE Trans. PAS, Vol. PAS-88, No. 4, April 1969, pp 388-399

[3]Lehn, P.; Rittiger, J.; Kulicke, B. ; "Comparison of the ATP Version of the EMTP and the NETOMAC Program for Simulation of HVDC Systems" IEEE Trans. Power Delivery, Vol. 10, No. 4, Oct. 1995, pp. 2048-2053.

[4]K.H. Krueger, R.H. Lasseter, "HVDC Simulation Using NETOMAC", IEEE Montech '86, Conference on HVDC Power Transmission, Montreal, Canada 1986

[5]A.M. Gole, I.T. Fernando, G.D. Irwin, O.B. Nayak, "Modeling of Power Electronic Apparatus: Additional Interpolation Issues", International Conference on Power System Transients,

IPST'97, Seattle, June 22-26, 1997, Proceedings: pp 23-28

[6] Power Delivery, Vol 15 No. 1, Jan 2000, pp 57-61

[7] Morched, A.; Gustavsen, B.; Tartibi, M.; "A Universal Model for Accurate Calculation of Electromagnetic Transients on Overhead Lines and Underground Cables", IEEE Trans. Power Delivery, Vol. 14 No. 3, July 1999 pp 1032-1038

[8] Nguyen, H.V.; Dommel, H.W.; Marti, J.R.; "Direct Phase-domain Modeling of Frequency-dependent Overhead Transmission Lines", IEEE Trans. Power Delivery, Vol. 12, No. 3, July 1997, pp. 1335-1342

[9] Noda, T.; Nagaoka, T. and Ametani, A.; "Phase Domain Modeling of Frequency Dependant Transmission Lines by Means of an ARMA model", IEEE Trans. Power Delivery, vol 12. No. 3, pp. 1335-1342, July 1997.

[10] Menzies, R.W.; Yiping Zhuang; "Advanced Static Compensation Using a Multilevel GTO Thyristor Inverter", IEEE Trans. Power Delivery, Vol. 10 No. 2 , April 1995 pp: 732 -738

[11] K. Sadek , M. Pereira,D.P. Brandt , A.M. Gole and A. Daneshpooy; "A.Capacitor Commutated Converter Circuit Configurations for Dc Transmission", IEEE PES Winter Meeting, Tampa, Fl., Feb 1998.

[12] Sybille, G.; Brunelle, P.; Hoang Le-Huy; Dessaint, L.A.; Al-Haddad, K.; "Theory and applications of power system blockset, a MATLAB/Simulink-based simulation tool for power systems" Proc. IEEE PES Winter Meeting, Singapore, Ja. 23-27, 2000, vol.1, pp 774 -779.

[13] A.M. Gole, P. Demchenko, D. Kell and G.D. Irwin; "Integrating Electromagnetic Transient Simulation with Other Design Tools" International Conference on Power Systems Transients, (IPST '2001), Rio de Janeiro, Brazil, June, 2001.

[14] Kuffel, R.; Giesbrecht, J.; Maguire, T.; Wierckx, R.P.; Forsyth, P.A.; McLaren, P.G.; "A Fully Digital Real-time Simulator for Protective Relay Testing", , Sixth International Conference on Developments in Power System Protection(Conf. Publ. No. 434) , 1997 Pp: 147 -150.

[15] Marti, J.R.; Hollman, J.A.; Calvino-Fraga, "Implementation of a Real-Time Distributed Network Simulator with PC-Cluster", International Conference on Parallel Computing in Electrical Engineering, 2000. (PARELEC 2000).

[16] Devaux, O.; Levacher, L.; Huet, O. , "An Advanced and Powerful Real-time Digital Transient Network Analyser, IEEE Trans. Power Delivery, Vol. 13, No. 2, April 1998, pp. 421 -426

[17] D.A. Woodford, A.M. Gole and R.W. Menzies, July 1982, "Digital Modeling of DC Links and Synchronous Machines", IEEE Trans. on PAS, Vol. PAS-102, no.6, June 1983, pp. 1616-1623.

[18] Woodford, D.A.; Reformat, M. and Gole, A.M.,"The Operation and Control Of Vsc Transmission", The Conference Of The Electric Power Supply Industry (CEPSI 2000), October 23-27, 2000; Manila, Phillipines.

[19] A.M. Gole, S.A. Woodford, J.E. Nordstrom, G.D. Irwin; "A Fully Interpolated Controls Library for Electromagnetic Transients Simulation of Power Electronic Systems", International Conference on Power Systems Transients, (IPST '2001), Rio de Janeiro, Brazil, June, 2001.

[20] G. Ivkovic, A.M. Gole, R.W. Menzies and D.R. Friesen; "Transient Modeling of the Written Pole Motor", Int. Conf. on Elec. Machines (ICEM 2000) Helsinki, Finland, Aug. 2000.

[21] Annakkage, U.D.; McLaren, P.G.; Dirks, E.; Jayasinghe, R.P.; Parker, A.D.; "A current trans-

Agenda - Executive Policy Committee - January 9, 2002