MODELING OF ELECTRICITY CAPACITY EXPANSIONS IN A REGIONAL FRAMEWORK OF THE ASEAN NATIONS AND YUNNAN PROVINCE PRC

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SUMMARY

The October 2003 "Bali Concord II" was signed by the ten ASEAN (Association of South East Asian Nations – Brunei, Cambodia, Indonesia, Loas, Malasia, Myanmar, Philippines, Singapore, Thailand, and Vietnam) which is an ambitious accord for establishing a plan for the removal of trade barriers and the deepening of regional integration. Trade among ASEAN nations amounted to $44 Billion in 1993 and grew to $73 Billion in 1998 representing a 13% annual growth rate. If this trend is to also embrace the energy trade of the region then significant savings are to be made. Demonstration results from the Purdue long-term electricity trade and capacity expansion model indicates savings in excess of $11 Billion dollars over the next 10 years assuming free trade of electricity and full regional cooperation taking place among ASEAN electricity utilities. Regional integration for planning of new generation and strategic international transmission lines is a significant strategy for ASEAN's rapidly expanding economies.

The Purdue ASEAN Regional Model Demonstration Results, 2004 - 2014

ASEAN Electricity 2004 to 2014	ASEAN Total Regional Electricity Costs ($ Billion) (Generation & Transmission)	Cost Savings (Investment & Operational)
Free Trade	99.14	10.4%
No Trade	110.70	0.0

Source: Appendices 1,2,3

RATIONALE

The rational for the proposed Purdue ASEAN modeling study is to provide a joint optimization of expanding both the transmission and generation expansions across the whole ASEAN region. The Purdue ASEAN optimization will overcome the shortcomings of earlier studies. A significant modeling exercise for an expanded transmission grid has taken place for the Greater Mekong Subregion (GMS -Mekong Power Grid Master Plan). What about regional interconnection for the whole ASEAN region with the inclusion of the most cost effective generation expansions? The Purdue University Energy Modeling Research Groups have undertaken this type of planning for the Midwest U.S. as well as for the 12 nations of the Southern African Power Pool (SAPP) and the 14 nations of the West African Power Pool (WAPP). This proposal outlines the benefits and work involved for an ASEAN wide integrated transmission with generation capacity expansion plan. At the 2003 Bali meeting the Chinese and SEAN delegations endorsed a three year program under the ASEAN-China Free Trade Area (ACFTA). To illustrate the benefits of including China in an ASEAN power pooling structure the proposed model in this document includes the southern Chinese province of Hunnan.

Several major policy issues confront the ASEAN energy planners. These include the future plans for new hydropower stations in the region, the use of natural gas from the regions combined massive reserves of over 256Tcf (167Tcf reserves in the U.S.A., 394Tcf in Qatar)

and the restructuring of the state controlled utilities, and the continuing debate over the environmental impact of the large hydro and thermal units connected to the grid which, while they allow low cost electricity to the region produce highly visible pollution consequences. In 2003 the governor of Thailand's Electricity Generating Authority (EGAT) stated his country's top three electricity priorities to be (a) privatization, (b) the Salween Hydropower Station in Myanmar, and (c) the regional power grid (involving Thailand, Malasia, Myanmar, Indonesia, Laos, Cambodia, Vietnam and Singapore). These three areas of policy are repeated priorities for most ASEAN member states.

Based on regional data already available and the initial modeling already conducted it now proposed that an extensive ASIAN and Yunnan regional expansion modeling study be conducted. This will demonstrate the benefits from greater regional cooperation and show the most cost effective (cost minimizing) expansion projects for investment.

PURDUE ASEAN MODELING ENHANCEMENTS

The study conducted by the NorConsult is an excellent start in the region's initiative for regional energy planning [1]. Certain enhancements are now proposed with the Purdue modeling proposal. These include:

(1) Regional long-term planning of both transmission and generation in all 10 nations of ASEAN including the benefits of under water power transmission cable. This model will also include the hydropower supply of the Yunnan Province and therefore also include the integration of China into the modeling scenarios.

(2) The Purdue models will provide an optimization methodology with cost minimization for operational as well as fixed capital costs. Both generation and transmission capacity expansions will be considered simultaneously.

(3) The electricity forecasting for the region and uncertainties in demand will have enormous consequences on all of the ASEAN long-term plans and this will require special attention to provide more detailed and accurate forecasts reflecting commercial, residential, and industrial sector consumption.

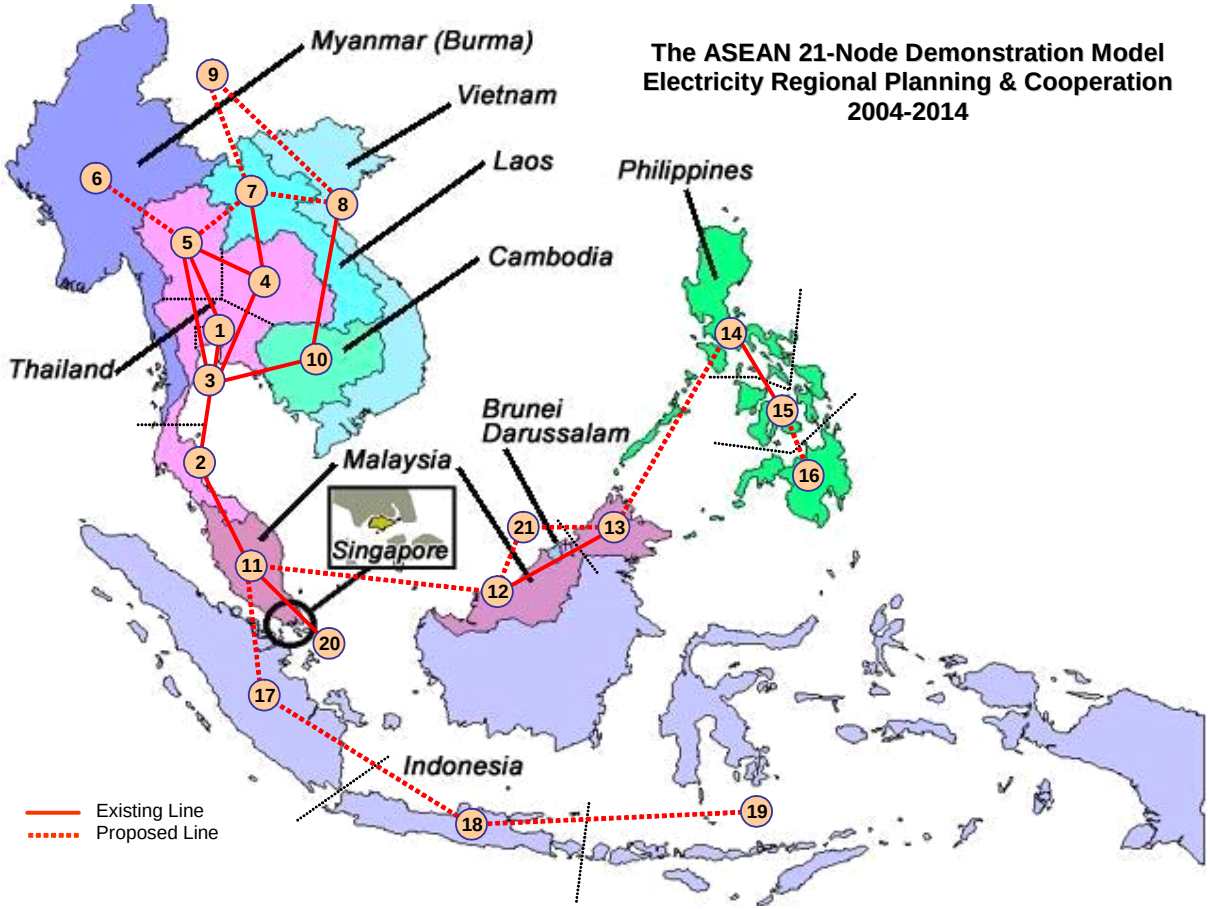
(4) Improved regional modeling to cope water inflows into the hydro schemes, environmental impact of large scale up-stream dams on lower regions, accuracy in expansion costs over a 10 or 20 year planning horizon.

(5) The demonstration of a regional ASEAN with Yunnan long-term capacity expansion plan. Initial demonstration results are provided in this proposal. Results can only be considered following a comprehensive and detailed regional data collection project for existing and proposed generation and transmission systems. The Purdue model will provide ASEAN with primarily an economic model.

(6) The inclusion of realistic distributed generation options at each node of the model to more accurately capture the competition between centrally generated electricity provided by the grid and locally generated electricity provided by small diesel or gas powered generation systems.

(7) The inclusion of the environmental impact of new generation units, including air emissions from thermal units, and the social impact of the large scale reservoir construction.
(8) The ability to provide decision makers with a set of locational marginal prices (LMP) at each node. These LMPs show the true cost of providing additional electricity at each node useful for rate setting at these nodes and difference between adjacent node LMPs provide signals for the construction of new transmission capacity.
(9) The Purdue modeling will build upon the Mekong integrated transmission system recommendations of earlier studies. The benefits of trade from a fully interconnected regional grid will be quantified. The demonstration model in this proposal shows cost savings in the order of 10% from free trade of electricity in the region.
(10) It is proposed that a 21 node model can be considered in the first phase of the modeling work (Figure 1). It can be seen that five nodes are provided for the regions of Thailand, three nodes for Malaysia, Philippines, and Indonesia.
(11) This proposal demonstrates the type of results that ASEAN may expect in an initial year of modeling with the Purdue team. Consider Appendices 1, 2 and 3.

Figure 1. The ASEAN 21 Node Demonstration Model



MODELING THE ASEAN REGION

Such major developments in generation and transmission expansions are taking place in the ASEAN that there is an excellent case for promoting quantitative modeling work to assist in the major decisions that are confronting the energy ministers of the region.

The expected results from the proposed Purdue modeling study include:

- Reduced cost of expansion.
- Improved demand forecasts.
- Consideration of externalities such as big hydro on down stream areas.
- Consideration pipeline as an option to replace undersea power line.
- Optimal consumption of the ASEAN natural gas reserves.

The ASEAN region has over 108 GW of generating capacity (Table 1) with much of the 2004 generation taking place in Indonesia, Malasia, the Philippines and Vietnam. The ASEAN data in Table 1 is the most recent 2004 data that includes new hydropower in Vietnam [1]. There is rapid growth in electricity demand across the whole region with 6.4% per annum in Thailand, 10% in much of Indonesia, 12% in Cambodia, 5.7% in Singapore, and 5.8% in Yunnan Province (Table 2). The 2004 regional peak demand is 68,401 MW and by 2014 this is forecast to be more than doubled at 143,658 MW.

Table 1. 2004 ASEAN Generation in the Demonstration Model (MW)

Node	Existing Thermal	Existing Hydropower	TOTAL
Thailand-Bangkok-1	3,121	0	3121
Thailand South – 2	8,618	331	8,949
Thailand Central – 3	7,651	1,058	8,709
Thailand East – 4	710	744	1,454
Thailand North – 5	2,799	1,253	4,052
Myanmar – 6	912	390	1,302
Laos – 7	9	643	652
Vietnam – 8	6,903	4,368	11,271
Yunnan PRC – 9	2,719	6,400	9,119
Cambodia – 10	143	0	143
Malayasia Peninsula – 11	13,663	2,092	15,755
Malayasia Sarawak – 12	723	94	817
Malayasia Sabah – 13	714	71	785
Philippines Luzon – 14	10,435	1,781	12,216
Philippines Visayas – 15	1,579	0	1,579
Philippines Mindanao - 16	669	1,004	1,673
Indonesia Sumatra – 17	1,081	458	1,539
Indonesia Java – 18	13,394	2,100	15,494
Indonesia East – 19	3,569	458	4,027
Singapore – 20	8,919	0	8,919
Brunei - 21	707	0	707
TOTAL	89,038	23,245	112,283

Sources: GMS Final Report Volume III June 2002, ASEAN Centre for Energy 200-2001, Philippines Department of Energy 2003,Investment Coordinating Board Indonesia 2002, US Embassy in Singapore 2003

Table 2. Existing Peak and Demand Growth in GMS and ASEAN Countries for 2004-2014

Country SuperNode	Population Pop	2004-Current Peak Demand	2014-Projected Peak Demand	N	Region Node	Peak Demand	Generation Sale	Demand Growth	Ten-Year Growth
	M	MW	MW			MW	GWh	%	Factor
Thailand	61.80	16682	31022	**1**	Thailand-MEA	7053	9034	6.4	1.860
				2	Thailand-South	1165	6680	6.4	1.860
				3	Thailand-Central	5565	69138	6.4	1.860
				4	Thailand-Northeast	1322	3440	6.4	1.860
				5	Thailand-North	1577	20721	6.4	1.860
Myanmar	48.10	780	1593	**6**	Myanmar	780	4401	7.4	2.042
Lao PDR	5.10	167	361	**7**	Lao PDR	167	865	8.0	2.159
Vietnam	76.30	4890	11899	**8**	Vietnam	4890	26722	9.3	2.433
Yunnan, PRC	41.90	5257	9238	**9**	Yunnan, PRC	5257	31635	5.8	1.757
Cambodia	11.60	114	364	**10**	Cambodia	114	586	12.3	3.190
Malaysia	23.80	10866	25252	**11**	Malaysia-Peninsula	10060	56210	8.9	2.339
				12	Malaysia-Sarawak	543	2874	7.9	2.145
				13	Malaysia-Sabah	263	1913	7.7	2.105
Philippines	78.30	8509	16973	**14**	Philippines-Luzon	6454	40141	7.3	2.023
				15	Philippines-Visayas	1006	6257	7.5	2.061
				16	Philippines-Mindanao	1049	6524	5.8	1.757
Indonesia	209.00	16314	38644	**17**	Indonesia-Sumatra	1838	9954	10.1	2.629
				18	Indonesia-Java	12581	68137	8.6	2.292
				19	Indonesia-East	1895	10263	10.1	2.628
Singapore	4.10	4423	7700	**20**	Singapore	5,139	31,986	5.7	1.741
Brunei	0.34	399	614	**21**	Brunei	399	2621	4.4	1.538
Total	560.34	68401	143658						

Sources: World Bank Report 2000-2001, Institute of Energy Economics Japan 2002, GMS Report Volume II June 2002, Japanese Committee for Pacific Coal Flow 2002-2001, Philippines Department of Energy 2003, Investment Coordinating Board Indonesia 2002, ASEA Center for Energy 2003

The hydropower potential of the region is a major planning activity (Table 3). The future size of the role of natural gas is also a major topic of debate. Hydropower in the Mekong Subregion and Yunnan is well documented [1]. The extensive reserves of natural gas in Indonesia and Malasia also will play an important part in regional energy trade modeling. The regional ASEAN demonstration model is illustrated in Figure 1 with descriptions of each node given in Table 4.

Table 3. Natural Gas Potential in ASEAN and China

Country	Natural Gas Reserves (TCF)
Thailand	13.3
Myanmar	10.0
Laos	0.0
Vietnam	6.8
China	53.3
Cambodia	0.0
Malaysia	75
Philippines	3.8
Indonesia	92.5
Singapore	0
Brunei	13.8

Source: http://www.eia.doe.gov/emeu/cabs/cabsfe.html

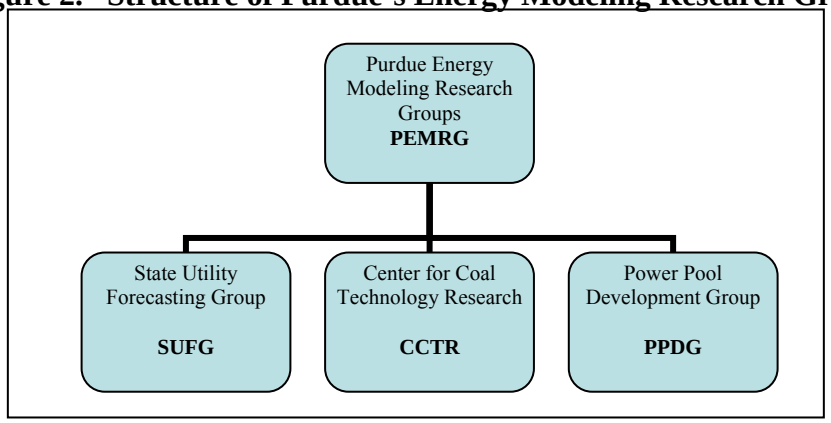
Table 4. The 21 Nodes in the Demonstration ASEAN Yunnan Model

Country SuperNode	Node Number	Region Node
Thailand	**1**	Thailand-MEA
	2	Thailand-South
	3	Thailand-Central
	4	Thailand-Northeast
	5	Thailand-North
Myanmar	**6**	Myanmar
Lao PDR	**7**	Lao PDR
Vietnam	**8**	Vietnam
Yunnan, PRC	**9**	Yunnan, PRC
Cambodia	**10**	Cambodia
Malaysia	**11**	Malaysia-Peninsula
	12	Malaysia-Sarawak
	13	Malaysia-Sabah
Philippines	**14**	Philippines-Luzon
	15	Philippines-Visayas
	16	Philippines-Mindanao
Indonesia	**17**	Indonesia-Sumatra
	18	Indonesia-Java
	19	Indonesia-East
Singapore	**20**	Singapore
Brunei	**21**	Brunei

PEMRG AND REGIONAL POWER POOL POLICY ANALYSIS

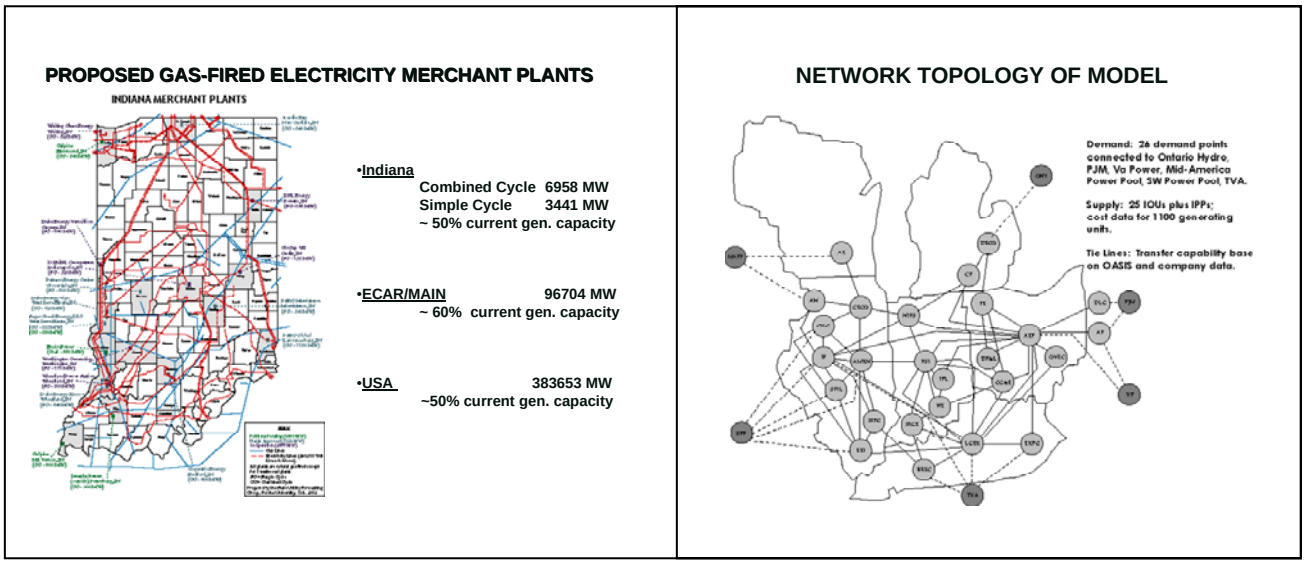
The Purdue Energy Modeling Research Groups (PEMRG) consist of a number of allied research groups at Purdue University, all of which are involved in research involving energy supply, transportation, and consumption. The principal PEMRG entity involved in this proposal is the State Utility Forecasting Group (SUFG). The primary function of SUFG is to develop and maintain an electricity forecasting model for the Indiana Utility Regulatory Commission (IURC), the local regulatory authority. SUFG has also been performing various analyses of the electricity industry since its formation in 1985.

Figure 2. Structure of Purdue's Energy Modeling Research Groups



Throughout its existence, SUFG has developed several local and regional models to address various possible market configurations. While SUFG's early focus has been primarily on the electricity industry, it has also developed a regional natural gas supply, transportation, storage, and utilization model [2-5].

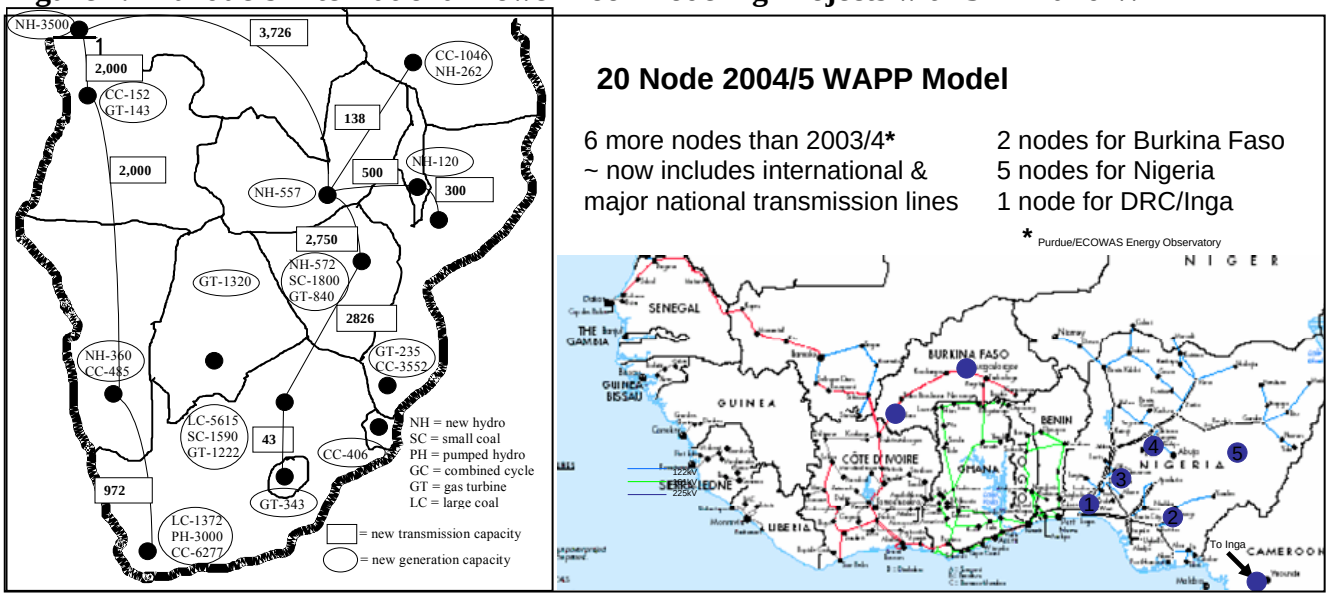
Figure 3. Purdue's Energy Modeling Work in the U.S. Midwest (Natural Gas and Electricity)



The SUFG traditional regulation forecasting modeling system is of particular interest for this project. The very first modeling system developed by SUFG, this modeling system projects electricity demand, supply and price for each electric utility in the state of Indiana assuming continued regulation. The modeling system captures dynamic interactions between customer demand, utility's operating and investment decisions and customer rates by cycling through various submodels until a price and energy equilibrium is attained. The residential, commercial, and industrial sector-specific energy models are key components of this modeling system. These models are a combination of econometric and end-use forecasting models that project energy consumption for a 20 year period. The SUFG modeling system is unique among utility forecasting and planning models because of its comprehensive and integrated characteristics.

Another PEMRG research group, the Power Pool Development Group (PPDG), has developed electricity trade and planning models for newly emerging regional power pools. PPDG is well versed in coordinating model construction and data collection efforts with personnel located far from Purdue.

Figure 4. Purdue's International Power Pool Modeling Projects with SAPP and WAPP



PPDG also has a great deal of experience organizing and conducting informational workshops and short courses, both at Purdue and in other countries. Its work with the Southern Africa Power Pool (SAPP) and the West African Power Pool (WAPP) has established an international scope to the modeling work of PEMRG. The SUFG technical expertise and PPDG international modeling partnerships experience place the PEMRG as an ideal choice for working with the ASEAN energy planners to establish a regional long-term electricity expansion plan and power pooling infrastructure [12-22].

ASEAN DEMONSTRATION REGIONAL TRADE MODEL

The ASEAN electricity trade and capacity expansion long-term model is described fully in the Purdue website [2,3] with special reference to the pool infrastructure development work with the Southern African Power Pool (SAPP) and the West African Power Pool (WAPP). Full details of the modeling background and formulation as well as a general training manual are available in the literature [4, 5].

The ASEAN region has so many developments taking place in the electricity sector from investment in new hydropower plants to major international investments being considered. Restructuring, privatization in all the energy industries, the trans ASEAN Gas Pipeline, private and foreign investment, future of IPPs, and promotion of competitive arrangements in the ASEAN energy markets are all major issues across ASEAN states today [6-11].

The ASEAN region and Yunnan Province PRC is a vast geographical area with a population of over 560M people needing electricity (Table 2). It is an area with great energy potential in its rivers and natural gas resources. It is essential therefore that this appropriate energy resource data and proposed new generation and transmission projects are included in the optimization work (for cost minimization). Table 5 summarizes the energy sources in each of the countries of the proposed model.

Table 5. Generation Potential in ASEAN and Yunnan

Key: H - Hydropower Potential, NG - Natural Gas power generation
Coal - Coal power generation, Oil - Oil fired generation
Nuc - Nuclear power generation, Geo - Geothermal power potential
Export - Planning for potential power exports, Import - Planning for potential power imports

Country	H	NG	Coal	Oil	Nuc	Geo	Export	Import
Cambodia	✓	-	-	✓	-		-	✓
Thailand	-	✓	✓	-	-	-	-	✓
Laos	✓	-	-	-	-	-	✓	-
Vietnam	✓	✓	✓	✓	✓	✓	-	-
Yunnan	✓	-	✓	-	-	-	✓	-
Myanmar	✓	✓	✓	✓	-	-	✓	-
Malaysia	✓	✓	✓	-	-	-	-	-
Indonesia	✓	✓	✓	-	-	✓	-	-
Philippines	-	✓	-	-	-	✓	-	-
Singapore	-	✓	-	✓	-	-	-	-
Brunei	-	✓	-	-	-	-	-	-

Table 6. Modeling Proposed New Generation (MW)

Country SuperNode	N	Region Node	Proposed Thermal MW	Proposed Hydro MW
Thailand	**1**	Thailand-MEA	0	0
	2	Thailand-South	3414	0
	3	Thailand-Central	6946	660
	4	Thailand-Northeast	0	0
	5	Thailand-North	0	0
Myanmar	**6**	Myanmar	100	7213
Lao PDR	**7**	Lao PDR	720	5444
Vietnam	**8**	Vietnam	6735	4671
Yunnan, PRC	**9**	Yunnan, PRC	3600	8650
Cambodia	**10**	Cambodia	330	228
Malaysia	**11**	Malaysia-Peninsula	15421	600
	12	Malaysia-Sarawak	1000	0
	13	Malaysia-Sabah	1000	0
Philippines	**14**	Philippines-Luzon	5430	0
	15	Philippines-Visayas	1050	0
	16	Philippines-Mindanao	750	0
Indonesia	**17**	Indonesia-Sumatra	5000	0
	18	Indonesia-Java	20000	0
	19	Indonesia-East	5000	0
Singapore	**20**	Singapore	8000	0
Brunei	**21**	Brunei	1000	0
		Total	85496	27466

Source: GMS Final Report Volume III June 2002, Philippines Department of Energy 200

Two sets of generation data are inserted into the ASEAN model:

(a) Existing generation capacity for each country/node (Table 1).
(b) Proposed new generation projects for which no decision has yet been taken (Table 6).

The capital cost data for the set of proposed new generation in the model if too high will tend not to be selected in the optimization process. Similarly if the fuel and operational costs are very high in the existing power stations then these will tend not to be switched on in favor of long-term cheaper to run new stations.

The transmission lines that interconnect each node are required for trade to take place and for the gains from deeper regional integration in energy trading to be realized. The existing lines in the region have estimated values placed in the ASEAN Demonstration Model (Table 7). These lines are given a load carrying capability of 250MW and if the demand for trade is high these existing lines are permitted to expand their capacity as much as is needed for keeping the total regional costs to a minimum (10,000MW is the parameter value for the limit on line expansion). New proposed transmission lines (overland and submarine) with initial capacities of 500MW are available (Table 8).

Table 7. Existing Transmission Load Carrying Capability in the Demonstration ASEAN Model

Node	Node	Load (MW)
MEA-1	Central-3	250
MEA-1	North-5	250
South-2	Central-3	250
South-2	Malaysia Peninsula-11	250
Central-3	Northeast-4	250
Central-3	North-5	250
Central-3	Cambodia-10	250
Northeast-4	North-5	250
Northeast-4	Laos-7	250
Vietnam-8	Cambodia-10	250
Malaysia Peninsula-11	Singapore-20	250
Malaysia Sarawak-12	Malaysia Sabah-13	250
Philippines Luzon-14	Philippines Visayas-15	250
Total		3,250

Source: Initial values used in demonstration optimization

Table 8. Proposed International Transmission Capacities in the ASEAN Region

Line	Region Node From	Node-Node	Region Node To	Existing Line Cap Original MW	Existing Line Cap Expanded MW	Proposed Line Cap Initial MW	Proposed Line Cap Expanded MW
1	Thailand-MEA	**1–3**	Thailand-Central	250	10000	-	-
2	Thailand-MEA	**1–5**	Thailand-North	250	10000	-	-
3	Thailand-South	**2–3**	Thailand-Central	250	10000	-	-
4	Thailand-Central	**3–4**	Thailand-Northeast	250	10000	-	-
5	Thailand-Central	**3–5**	Thailand-North	250	10000	-	-
6	Thailand-Northeast	**4–5**	Thailand-North	250	10000	-	-
7	Thailand-Northeast	**4–7**	Lao PDR	250	10000	-	-
8	Vietnam	**8–10**	Cambodia	250	10000	-	-
9	Thailand-Central	**3–10**	Cambodia	250	10000	-	-
10	Thailand-South	**2–11**	Malaysia-Peninsula	250	10000	-	-
11	Malaysia-Peninsula	**11–20**	Singapore	250	10000	-	-
12	Malaysia-Sarawak	**12–13**	Malaysia-Sabah	250	10000	-	-
13	Philippines-Luzon	**14–15**	Philippines-Visayas	250	10000	-	-
14	Thailand-North	**5–6**	Myanmar	-	-	500	10000
15	Thailand-North	**5–7**	Lao PDR	-	-	500	10000
16	Lao PDR	**7–8**	Vietnam	-	-	500	10000
17	Lao PDR	**7–9**	Yunnan, PRC	-	-	500	10000
18	Vietnam	**8–9**	Yunnan, PRC	-	-	500	10000
19	Malaysia-Peninsula	**11–12**	Malaysia-Sarawak	-	-	500	50000
20	Malaysia-Sarawak	**12–21**	Brunei	-	-	500	10000
21	Malaysia-Sabah	**13–21**	Brunei	-	-	500	10000
22	Malaysia-Sabah	**13–14**	Philippines-Luzon	-	-	500	10000
23	Philippines-Visayas	**15–16**	Philippines-Mindanao	-	-	500	10000
24	Malaysia-Peninsula	**11–17**	Indonesia-Sumatra	-	-	500	10000
25	Indonesia-Sumatra	**17–18**	Indonesia-Java	-	-	500	10000
26	Indonesia-Java	**18–19**	Indonesia-East	-	-	500	10000

Modeling Activities - Regional Planners and Purdue University

Several areas of modeling are envisaged that will be of importance to the member states of ASIAN and of very much interest to the ASEAN energy planners. With a three year quantitative modeling activity in the region a scope of work is outlined below. Demonstration results from an initial Purdue ASEAN model are shown in Appendix 3.

Following initial consultations with ASEAN the items below can be prioritized:

(a) During the first six months of the proposed collaborative modeling activity there will be data collection training sessions and a comprehensive regional data set compiled of all existing generation stations and transmission lines as well as proposed new stations and lines.
(b) Training sessions will take place in the use of the long-term electricity trade model with the user friendly interface so that as the modeling of ASEAN policy develops there will be effective technology transfer and the region will have its own capability for using this decision support tool and not be dependent upon Purdue staff for its use in the long-term.
(c) The existing ASEAN demand data and forecasting techniques will be used in the first year of the modeling project and during this first year an appraisal will be made of the present methodology of demand forecasting and training can be provided for data collection that represents sectoral demand for the residential, commercial and industrial customers.
(d) The electricity trade autonomy factors will demonstrate the effects of different of centrally coordinated energy trading. The cost savings from flexible trading compared with bilateral agreements can be carefully assessed once the first ASEAS data set has been compiled.
(e) Hydrological data is expected to have added importance to the ASEAN modeling as large new major hydropower projects are being considered in the region.
(f) An initial ASEAN pool plan can be drafted that will demonstrate the use of sensitivity analysis techniques of the modeling for the selection of the most cost effective new projects. This training will be of great value once the region has an accurate data set and the costing of projects has been carefully assessed.
(g) There are many large islands in the community. The mix of population size and demand as well as the high cost of submarine cables is likely to prefer the implementation of distributed generation. Isolated areas of the region are likely to need this technology and the model will assess this in the optimization.
(h) Environmental impact of new power stations and the effects of drought are important scenarios to be considered.
(i) Pricing policy of trade and national prices will be investigated.

The policy scenarios, number of regional nodes, and planning priorities will be discussed during the first consultation meeting between the ASEAN planners and the Purdue team.

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Appendix 1

Appendix 1(A) GENERATION CAPACITY EXPANSION WITH FREE TRADE, 2004 – 2014 (MW)

	Old Thermal	Comb Cycle	Small Coal	Large Coal	Gas Turbine	Old Hydro	New Hydro	IPP Tier 1	IPP Tier 2	Total
MEA-1	0	0	0	0	0	0	0	0	0	0
South-2	0	3,414	0	0	0	0	0	0	0	3,414
Central-3	0	6,946	0	0	0	0	530	0	0	7,476
Northeast-4	0	0	0	0	0	0	0	0	0	0
North-5	0	0	0	0	0	0	0	0	0	0
Myanmar-6	0	0	0	0	0	0	1,117	0	0	1,117
Laos-7	0	0	0	0	0	0	4,032	0	0	4,032
Vietnam-8	0	408	0	0	0	0	4,032	0	0	4,440
Yunnan PRC-9	0	0	0	0	0	0	1,742	0	0	1,742
Cambodia-10	0	330	0	0	0	0	0	0	0	330
a Peninsula-11	0	12,102	0	0	0	0	600	0	0	12,702
sia Sarawak-12	0	563	0	0	0	0	0	0	0	563
aysia Sabah-13	0	888	0	0	0	0	0	0	0	888
pines Luzon-14	0	5,430	0	0	0	0	0	0	0	5,430
nes Visayas-15	0	1,050	0	0	0	0	0	0	0	1,050
es Mindanao-16	0	750	0	0	0	0	0	0	0	750
sia Sumatra-17	0	4,387	0	0	0	0	0	0	0	4,387
onesia Java-18	0	19,319	0	0	0	0	0	0	0	19,319
onesia East-19	0	2,871	0	0	0	0	0	0	0	2,871
Singapore-20	0	6,094	0	0	0	0	0	0	0	6,094
Brunei-21	0	466	0	0	0	0	0	0	0	466
Total	0	65.2E3	0	0	0	0	12.1E3	0	0	77,071

Appendix 1(B) TOTAL COST WITH FREE TRADE, 2004 – 2014 ($)

Region	T.C. w/o G.	T.C. w G.	Fixed O&M	Fuel Costs	G.C.Costs	T.C.Costs	U.E.	U. MW	V O&M	W. Costs
MEA-1	370.606E6	3.67905E9	0	83.1615E6	0	278.653E6	0	0	8.7917E6	0
South-2	3.46197E9	1.8222E9	10.4181E6	2.28213E9	625.087E6	98.6884E6	0	0	438.777E6	6.8735E6
Central-3	10.1104E9	20.3049E9	29.9885E6	6.32955E9	2.29255E9	156.88E6	0	0	1.26575E9	35.7033E6
Northeast-4	233.387E6	57.2112E6	0	0	0	186.984E6	0	0	30.9355E6	15.4678E6
North-5	109.763E6	4.05879E9	0	0	0	31.6314E6	0	0	52.0874E6	26.0437E6
Myanmar-6	711.523E6	355.79E6	294.58	0	612.593E6	0	0	0	65.9534E6	32.9767E6
Laos-7	3.78219E9	517105000	1238.74	0	3.41313E9	15.8157E6	0	0	235.493E6	117.746E6
Vietnam-8	5.00201E9	225406700	989555.	211.423E6	4.03727E9	126.997E6	0	0	430.188E6	195.147E6
Yunnan PRC-9	953.755E6	361.274E6	278.8	0	483.471E6	0	0	0	313.523E6	156.761E6
Cambodia-10	261.836E6	139.267E6	799718.	171.078E6	57.6767E6	0	0	0	32.2814E6	0
sia Peninsula-11	17.7403E9	16.9912E9	54.1254E6	11.4172E9	3.88014E9	56.1316E6	0	0	2.27329E9	59.4676E6
aysia Sarawak-12	928.841E6	935.813E6	2.75198E6	579.68E6	231.166E6	0	0	0	113.289E6	1.95349E6
alaysia Sabah-13	738.874E6	609.335E6	2.15214E6	460.391E6	180.779E6	4.25195E6	0	0	89.824E6	1.47551E6
ippines Luzon-14	11.59E9	11.4222E9	32.6154E6	8.06807E9	1.95692E9	0	0	0	1.49538E9	37.0056E6
pines Visayas-15	1.78131E9	2.36454E9	5.25548E6	1.11585E9	435.454E6	14.964E6	0	0	209.788E6	0
nes Mindanao-16	814.772E6	527.341E6	2.26268E6	481.141E6	177.997E6	0	0	0	132.51E6	20.8609E6
nesia Sumatra-17	3.87991E9	3.52234E9	15.3258E6	2.40997E9	919.548E6	51.7978E6	0	0	473.762E6	9.50777E6
ndonesia Java-18	22.4313E9	22.6046E9	80.9923E6	14.5838E9	4.85954E9	24.2339E6	0	0	2.83915E9	43.6418E6
ndonesia East-19	3.39204E9	3.27424E9	11.8593E6	2.22101E9	711.56E6	0	0	0	438.106E6	9.50777E6
Singapore-20	10.0012E9	10.0069E9	32.1472E6	6.76388E9	1.92883E9	0	0	0	1.2763E9	0
Brunei-21	849.238E6	850.721E6	2.53736E6	532.99E6	213.138E6	0	0	0	100.572E6	0
Total	99.1453E9	99.1453E9	284.223E6	57.7113E9	27.0169E9	1.04703E9	0	0	12.3158E9	770.14E6

Notes: "Old thermal" refers to existing thermal generating capacity. Specific generating technologies ("combined cycle", "small coal" etc refer to proposed new generating capacity. "IPP" refers to independent power producer contracts. "TC w/o G" refers to Total Regional Cost without gains from trade. "TC w G" refers to Total regional Cost with gains from trade. "O&M" is operational and maintenance cost. "GC Costs" are the costs of new Generation Capacity. "TC Costs" are the costs of new transmission capacity. "UE" is the Unserved Energy and "U.MW" is the unmet reserve power costs. "V O&M" is variable operations and maintenance cost. "W Costs" is the variable cost of water.

Appendix 2

Appendix 2(A) GENERATION CAPACITY EXPANSIONS – NO TRADE 2004 – 2014 (MW)

	Old Thermal	Comb Cycle	Small Coal	Large Coal	Gas Turbine	Old Hydro	New Hydro	IPP Tier 1	IPP Tier 2	Total
MEA-1	0	0	0	0	0	0	0	0	0	0
South-2	0	3,414	0	0	0	0	0	0	0	3,414
Central-3	0	6,946	0	0	0	0	530	0	0	7,476
Northeast-4	0	0	0	0	0	0	0	0	0	0
North-5	0	0	0	0	0	0	0	0	0	0
Myanmar-6	0	0	0	0	0	0	595	0	0	595
Laos-7	0	0	0	0	0	0	0	0	0	0
Vietnam-8	0	3,329	0	0	0	0	2,783	0	0	6,112
Yunnan PRC-9	0	2,067	0	0	0	0	730	0	0	2,797
Cambodia-10	0	254	0	0	0	0	0	0	0	254
a Peninsula-11	0	11,868	0	0	0	0	600	0	0	12,468
sia Sarawak-12	0	53	0	0	0	0	0	0	0	53
aysia Sabah-13	0	382	0	0	0	0	0	0	0	382
pines Luzon-14	0	5,430	0	0	0	0	0	0	0	5,430
nes Visayas-15	0	1,050	0	0	0	0	0	0	0	1,050
es Mindanao-16	0	750	0	0	0	0	0	0	0	750
sia Sumatra-17	0	4,951	0	0	0	0	0	0	0	4,951
onesia Java-18	0	19,321	0	0	0	0	0	0	0	19,321
onesia East-19	0	2,855	0	0	0	0	0	0	0	2,855
Singapore-20	0	6,123	0	0	0	0	0	0	0	6,123
Brunei-21	0	466	0	0	0	0	0	0	0	466
Total	0	69.6E3	0	0	0	0	5.23E3	0	0	74,497

Appendix 2(B) TOTAL COST WITH NO TRADE, 2004 – 2014 ($)

Region	T.C. w/o G.	T.C. w G.	Fixed O&M	Fuel Costs	G.C.Costs	T.C.Costs	U.E.	U. MW	V O&M	W. Costs
MEA-1	3.21617E9	5.78895E9	0	2.65666E9	0	278.653E6	0	0	280.857E6	0
South-2	6.87379E9	5.2414E9	21.5979E6	4.53354E9	1.29588E9	146.697E6	0	0	869.199E6	6.8735E6
Central-3	18.1724E9	17.6062E9	43.9425E6	12.76E9	3.12978E9	17.2678E6	0	0	2.18572E9	35.7033E6
Northeast-4	162.722E6	445.934E6	0	93.5894E6	0	12.8347E6	0	0	40.8296E6	15.4678E6
North-5	5.22535E9	5.22076E9	0	4.65448E9	0	678578.	0	0	544.152E6	26.0437E6
Myanmar-6	336.423E6	348.909E6	133.75	0	278.147E6	0	0	0	38.8504E6	19.4252E6
Laos-7	45.6337E6	-3.4048	0	0	0	12.1169E6	0	0	22.3445E6	11.1722E6
Vietnam-8	2.33585E9	1.94314E9	8.06885E6	0	1.92212E9	18.9108E6	0	0	257.834E6	128.917E6
Yunnan PRC-9	847.814E6	758.018E6	5.0086E6	0	453.83E6	0	0	0	259.317E6	129.658E6
Cambodia-10	278.505E6	267.252E6	998950.	172.865E6	72.0455E6	0	0	0	32.5958E6	0
sia Peninsula-11	18.0176E9	18.1472E9	55.1577E6	11.5754E9	3.94208E9	82.3073E6	0	0	2.30314E9	59.4676E6
aysia Sarawak-12	59.1318E6	49.5397E6	127565.	27.2892E6	10.7155E6	9.98977E6	0	0	9.05629E6	1.95349E6
alaysia Sabah-13	499.015E6	500.844E6	1.46325E6	309.523E6	122.913E6	2.28372E6	0	0	61.3561E6	1.47551E6
ippines Luzon-14	12.6376E9	12.4992E9	34.337E6	8.87409E9	2.06022E9	21.7156E6	0	0	1.61022E9	37.0056E6
pines Visayas-15	875.345E6	1.07872E9	2.54456E6	544.339E6	210.835E6	14.9132E6	0	0	102.713E6	0
nes Mindanao-16	814.772E6	760.283E6	2.26268E6	481.141E6	177.997E6	0	0	0	132.51E6	20.8609E6
nesia Sumatra-17	3.95672E9	3.85656E9	17.6688E6	2.3447E9	1.06013E9	63.2628E6	0	0	461.447E6	9.50777E6
ndonesia Java-18	22.4579E9	22.6378E9	81.0091E6	14.586E9	4.86055E9	47.1309E6	0	0	2.83958E9	43.6418E6
ndonesia East-19	3.025E9	2.94821E9	10.6635E6	1.9736E9	639.809E6	0	0	0	391.422E6	9.50777E6
Singapore-20	10.0147E9	9.79085E9	32.3018E6	6.76735E9	1.93811E9	0	0	0	1.27696E9	0
Brunei-21	851.104E6	847.86E6	2.53736E6	534.686E6	213.138E6	0	0	0	100.743E6	0
Total	110.704E9	110.704E9	319.69E6	72.8892E9	22.3883E9	728.762E6	0	0	13.8208E9	556.681E6

Notes: "Old thermal" refers to existing thermal generating capacity. Specific generating technologies ("combined cycle", "small coal" etc refer to proposed new generating capacity. "IPP" refers to independent power producer contracts. "TC w/o G" refers to Total Regional Cost without gains from trade. "TC w G" refers to Total regional Cost with gains from trade. "O&M" is operational and maintenance cost. "GC Costs" are the costs of new Generation Capacity. "TC Costs" are the costs of new transmission capacity. "UE" is the Unserved Energy and "U.MW" is the unmet reserve power costs. "V O&M" is variable operations and maintenance cost. "W Costs" is the variable cost of water.

Appendix 3

Purdue ASEAN Model Demonstration Results

This initial ASEAN demonstration model shows that with free trade of energy across the region that massive cost savings are to be made in the order of $11.9B over the ten year period, 2004 to 2014. This 10.7% total cost saving ($99.1B instead of $110.7B with no trade, Table 9) over ten shows demonstrates the great economic benefits to the region from promoting free trade of energy.

The total costs of new transmission capacity for the ten year planning horizon is over one billion dollars with no trade and if lines are built for security and reliability purposes only to supply reserve power then still an investment of $730M is to be expected. This level of investment is about 1% of the total cost for the ten year horizon and this is the most cost effective investment for the region. The infrastructure for energy transfer is a critical policy for the whole region. With free trade it is seen that more than $14B is saved from fuel costs for 2004 to 2014 (Table 9).

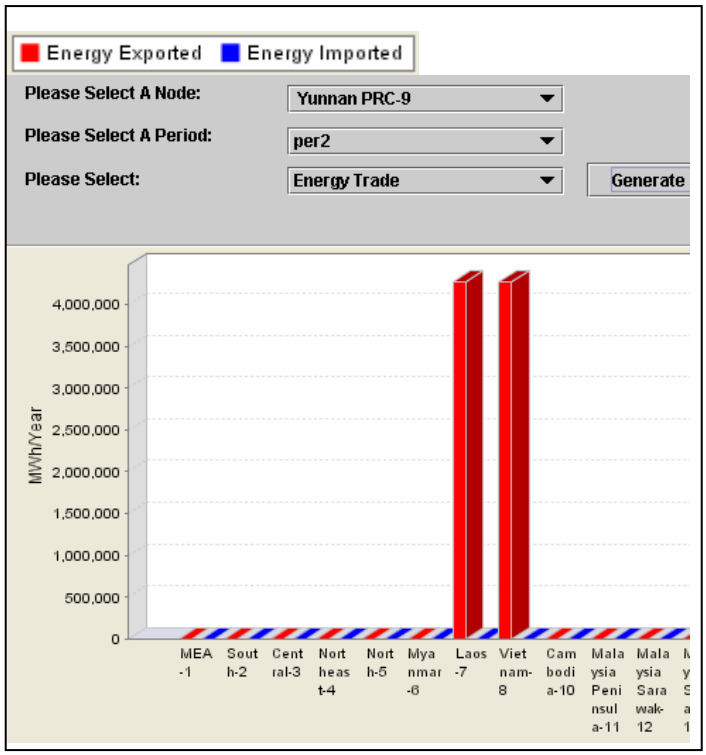
Table App 3. Demonstration ASEAN Model 2004 to 2014 Regional Costs with Free Trade and with No Trade Permitted

	New Generation Capacity (MW)	Total Regional Costs ($ Billion)	Total Regional Cost for New Generation ($ Billion)	Total Regional Cost for New Transmission ($ Billion)	Total Regional Cost for Fuel ($ Billion)
Free Trade	77,071	99.14	27.01	1.04	57.71
No Trade	74,497	110.70	22.38	0.73	72.88

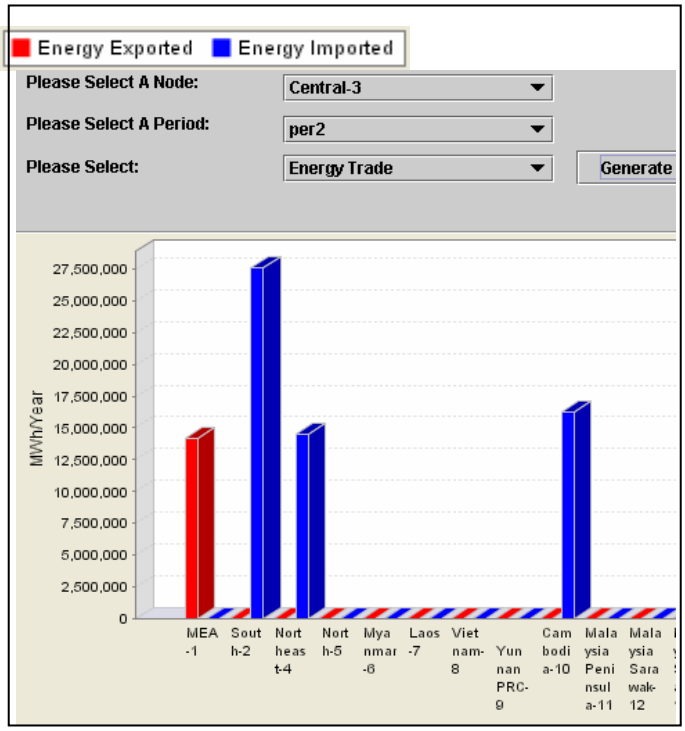
Further detailed results from the Purdue Demonstration ASEAN Long-Term Model are shown in Appendix 1. The capital investment costs, fuel and operational costs are shown for each country/node and the gains from trade for each are shown in columns two and three of the Table "B".

One of the values of the Purdue long-term model is the facility of the user-friendly interface that makes it easy to use for general planners. Appendix 3A and 3B illustrate some of the trade output screens. Appendix 3A shows the amounts of electricity traded from Yunnan Province during 2009 to 2014 (MWh/year) to Laos and Vietnam. Appendix 3B shows all of the imports and limited exports (wheeling?) at Thailand's Central Region.

Appendix 3A. Example of Free Trade – Yunnan Province to South East Asia



Appendix 3B. Example of Free Trade – Central Thailand and Region



Appendix 4A

Purdue Resumes

FREDERICK T. (TOM) SPARROW

Director, Center for Coal Technology Research, Purdue University
Director, Power Pool Development Group, Purdue University
Professor of Industrial Engineering, School of Industrial Engineering, Purdue University
Professor of Economics, Department of Economics, Krannert School of Management, Purdue
Adjunct Professor, Department of Agricultural Economics, Purdue University

1953	BS	Geology	University of Michigan
1956	MBA	Managerial Economics	Cornell University
1962	PhD	Economics and Operations Research	University of Michigan

On the staff of Purdue since 1978, Dr. Sparrow's teaching responsibilities include graduate courses in economic engineering analysis, and mathematical programming. Until 1999 he served as the director of the Schools of Engineering's Institute for Interdisciplinary Engineering Studies (IIES), which houses several centers, laboratories, and programs focused on particular problem areas such as biomedical engineering, renewable resources engineering, and transportation. From 1990 to August 2003 he served as the director of the State Utility Forecasting Group. Dr. Sparrow is currently the director of the Center for Coal Technology Research (CCTR), created at Purdue University by the Indiana legislature in 2002. Effective July 1, 2003, the legislation allows CCTR to implement public education programs and requires CCTR to appoint a panel of at least eight members, consisting of scientists, engineers, or other professionals, to review and make recommendations about applications for coal research grants.

Prior to his association with Purdue, Dr. Sparrow taught for 10 years at The Johns Hopkins University, as well as serving as chairperson of the Industrial Engineering Department at the University of Houston. He also worked for two years for the Atomic Energy Commission as an Operations Analyst, and for three years for the National Science Foundation, where his last appointment was Deputy Director for Planning and Evaluation for NSF's Research Applied to National Needs Directorate.

Dr. Sparrow's primary concerns are interdisciplinary, with an emphasis on energy modeling and analysis, electrotechnology commercialization, industrial electrification, and transportation. He is the author or co-author of more than 100 papers, presentations, and reports on these topics, as well as on matters relating to economics, operations research, and industrial engineering. His honors include selection as a Ford Foundation Research Professor and invitations to speak before various organizations in the U. S., Europe, and Japan. Dr. Sparrow is consultant to various government agencies, electric utilities, and to the iron and steel industry.

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Recent Publications:

Sparrow, F.T., Bowen, Brian H., and Aouam, Tarik, "Technology Options in West Africa's Electricity Generation Expansion Planning for 2003 to 2013," prepared for the West Africa Power Pool (WAPP) Meeting, Cotonou, Benin, February 17-25, 2003.

Bowen, B.H., Sparrow, F.T., Yu, Z., and Granum, G., "Economic Benefits From Integrated Electricity Markets," prepared for presentation at the South Asia Regional Initiative in Energy Training Program, July 19-23, 2003, Dhaka, Bangladesh.

State Utility Forecasting Group, Staff Report, "Indiana Electricity Projections: The 2003 Forecast," September 2003.

State Utility Forecasting Group, Staff Report, "2003 Indiana Renewable Energy Resources Study," September 2003.

Sparrow, F.T., Sanogo, Diakalia, and Bowen, Brian H., "Demonstration of Generation Expansions for 2002 to 2012," Power Pool Development Group Staff Report, March 25, 2002.

Yu, Z., Sparrow, F.T., Gotham, D.J., Holland, F.D., Nderitu, D.G., and Morin, T.L., "The Impact of Transmission on Imperfect Electricity Competition," Proceedings of the IEEE PES Winter Power Meeting 2001, New York, NY, January 2002.

Sparrow, F.T., Bowen, B.H., Yu, Z., "Regional Hydropower Policy and Capacity Expansion Modeling for the Countries of Southern Africa," International Water Power & Dam Construction, February 2001.

Recent Presentations:

Sparrow, F.T. and Holland, F.D., "The Supply and Demand for Indiana Electric Energy," presented to Indiana Conference on Energy, Indianapolis, IN, October 1, 2002.

Sparrow, F.T., "Factors Affecting Indiana Electricity Prices in (Not So?) Competitive Wholesale Markets," presented to the 2001 Indiana Energy Conference, Indianapolis, IN, November 8, 2001.

Sparrow, F.T., "Projections of Indiana Electricity Supply and Demand," presented to the Regulatory Flexibility Committee, Indianapolis, IN, August 23, 2001.

Sparrow, F.T., and Yu, Zuwei, "Simulating the Impact of Mergers and Other Wholesale Electricity Prices in Indiana," presented to the Electric Power Industry Special Institute Conference, Halifax, Canada, July 10-14, 2001.

Appendix 4B

BRIAN H. BOWEN

Potter Engineering Center, Room 270, Purdue University, West Lafayette, Indiana 47907, U.S.A.
Ph: 765-494-1873, Fax: 765-494-2351, Email: bhbowen@ecn.purdue.edu

Dr. Brian Bowen is a professional engineer and an associate research director at Purdue University's Power Pool Development Group (PPDG) with interests in energy policy and economic development. Full-time university engineering lectureships in Mauritius (1971-73), Sierra Leone (1974-86), and Zimbabwe (1990-93) were respectively sponsored by ODA-UK, British Council, and IVS-UK. Other university teaching positions were in the U.K. (1987-90, 1993-94) and at Purdue (1994-1997, 1998-99). Current Purdue responsibilities are to provide support to international collaborative partnerships for power pool modeling, and management of energy projects. From 1999 to present, major activities undertaken for the West Africa Power Pool (WAPP) have been training engineers in pool infrastructure modeling, data management, pool policy analysis; and developing a user-friendly interface for the power pool model. 1996 to 2001 concentrated on liaising between the Southern African Power Pool (SAPP) electricity planners and the Purdue modeling team, as they created and coded the long-term electricity trade model for determining the minimum costs of hydro-thermal capacity expansions (with transmission) for an integrated regional system (hydropower in the D.R.C. and thermal generation in the R.S.A.). Bowen has now been at Purdue for 10 years.

Academic, Professional Training

1998	Ph.D., Industrial Engineering, engineering economics, Purdue University, USA
1986	Grad.Dip.CAD/CAM, Liverpool John Moore University, UK
1985	M.Sc., Mechanical Engineering & Energy Studies, University College, Cardiff, UK
1978	C.Eng, M.I.Mech.E., Chartered Professional Engineer
1974	Grad.Dip.Education, Oxford University, UK
1971	B.Sc.Hons, Mechanical Engineering, Coventry University, UK

Collaborating Agencies, Companies

IURC, Indiana Utility Regulatory Commission
Indiana Dept of Commerce, Energy & Coal
Indiana Dept of Natural Resources
USAID Regional Center for Southern Africa
USAID West Africa Regional Office
PA Consulting, USA
AED, Academy for Educational Development
SADC, S. African Development Community
USAID Global Bureau
ERB, Energy Regulatory Board, Zambia
Sandia, National Laboratory, USA
AIRD, Assoc. Int. Resources & Development, USA
ARRDEL, Assoc Research Resources Development, UK
ECOWAS, Economic Comm. of W. African States
ALO, Association Liaison Office, USA
World Bank
Department of Energy, DOE, USA
Eskom, South Africa electricity corp.
ZIMCONSULT, Zimbabwe Energy Consultants
USEA, United States Energy Association

Employment, International Experience

2003-Present	Purdue University, Center for Coal Technology Research, CCTR Research Associate
1998-Present	Purdue University, Power Pool Development Group, PPDG Associate Research Director
1998-1999	Purdue University, School of Technology, Visiting Professor
1994-1998	Purdue University, Instructor & Research Associate
1993-1994	Manchester University & Manchester Metropolitan University, UK, Lecturer
1990-1993	University of Zimbabwe, Zimbabwe, Southern Africa (British Council), Lecturer
1987-1990	Liverpool John Moore University, UK, Lecturer
1974-1986	Fourah Bay College, University of Sierra Leone, West Africa (ODA-UK), Lecturer
1971-1973	University of Mauritius, Indian Ocean, (International Voluntary Service, UK), Lecturer
1964-1971	British Insulated Callenders Cables Ltd, UK, Technical Officer & Junior Engineer

Publications

Brian H. Bowen, Forrest D. Holland, F.T. Sparrow, Ronald L. Rardin, Douglas J. Gotham, Zuwei Yu, Anthony F. Black, "Expanding the Utilization of Indiana Coals", Indiana Center for Coal Technology Research and Indiana Department of Commerce, Indianapolis, August 18, 2004

F.T. Sparrow, Brian H. Bowen, Zuwei Yu, "Modeling Strategic International Transmission: Critical Planning Issues in Africa & the U.S.A.", IEEE PES 2004 General Meeting, Denver, USA, June 9, 2004

Zuwei Yu, F.T. Sparrow, Brian H. Bowen, "A Safety & Security Constrained Hydrothermal Scheduling Model System", IEEE PES 2004 General Meeting, Denver, USA, June 9, 2004

Z. Baha, F.T. Sparrow, M.Dyrenfurth, J.P.Lisack, D. Engi, B.H.Bowen, "Afghanistan's Socio-Technological Challenges", Seminar on Sciences, Technologies, and Higher Education in Agriculture, Technology, and Veterinary Science for Afghanistan Tomorrow, TUAT-UNESCO Tokyo, Japan, March 2, 2004

Brian H. Bowen, F.T. Sparrow, "The Benefits from Integrated Markets in Africa", Electricity Trading & Policy Analysis in Africa, London School of Economics, London, UK, August 18, 2003

Brian H. Bowen, F.T. Sparrow, Tarik Aouam, "Technology Options in West Africa's Electricity Generation Expansion Planning for 2003 to 2013", ECOWAS Regional Summit, Cotonou, Benin, February 17 to 25, 2003

J. Ayodele, F.T. Sparrow, B.H. Bowen, "WAPP Modeling Initiatives for Policy and Strategic Investments", ECOWAS Regional WAPP Meeting, Accra, Ghana, April 13-16,2004

O. Shokunbi, J. Ayodele, F.T. Sparrow, B.H. Bowen, "WAPP Modeling with Multiple Node Functionality", ECOWAS Regional WAPP Meeting, Accra, Ghana, April 13-16,2004

S. Kane, J. Ayodele, F.T. Sparrow, B.H. Bowen, "IPPs in the WAPP Modeling and Planning", ECOWAS Regional WAPP Meeting, Accra, Ghana, April 13-16,2004

Brian H. Bowen, F.T. Sparrow, "Current SAPP & WAPP Infrastructures", Electricity Trading & Policy Analysis in Africa, London School of Economics, London, UK, August 19, 2003

F.T. Sparrow, Brian H. Bowen, "Electricity Trade Analysis, Short-Term", Electricity Trading & Policy Analysis in Africa, London School of Economics, London, UK, August 18, 2003

F.T. Sparrow, Brian H. Bowen, "Electricity Trade Analysis, Long-Term", Electricity Trading & Policy Analysis in Africa, London School of Economics, London, UK, August 19, 2003

Brian H. Bowen, F.T. Sparrow, Geoff Granum, "Trading Arrangements in Power Pools Model Structure and Data", AED-USAID Strengthening Regional Energy Linkages in South Asia , Dhaka, Bangladesh, July 19-23, 2003.

Brian H. Bowen, F.T. Sparrow, Zuwei Yu, Muhammad Al-Salamah, "Policy Analysis in the Development of Integrated Middle East Regional Energy Markets", 8th Power Generation Conference, Dubai, United Arab Emirates, October 6 to 9, 2002.

Appendix 4C

ZUWEI YU

Sr. Analyst, and associate professor of courtesy appointment
Indiana State Utility Forecasting Group (SUFG), Purdue University
Room 334, 1293 Potter Engineering Center, W. Lafayette, IN 47907
Phone: (765) 494-4224(office). Emails: zyu@purdue.edu

EXPERIENCE

07/2003 – present: Lead a team in designing and lecturing a short course series of portfolio and risk management for the Indiana Utilities Regulatory Commission (IURC), and utilities in Indiana. Taking steps to expand the short course to other state commissions and utilities. Designing tools for benchmarking gas purchases of utilities and incentive regulation.

04/2002 – Dec. 2003: Co-Principle investigator and project administrator for a national electricity model. The project was focused on maintenance and operational scheduling with security and safety considerations for the Pacific Northwest.

07/2001 – 2003: A technical leader for a Midwest/Northeast gas market modeling group. The research involves gas demand, transportation, correlation, prices and interaction between gas and electricity and risk. Statistical, time series and optimization methods are used.

04/2001 – present: Associate professor - courtesy appointment, Purdue University.
Designed a course of financial engineering and a lab for engineering students.
And a principle investigator of a research project on Financial Engineering and Risk Management, including volatility & value at risk for energy markets, etc.

97 – present: A lead analyst in charge of deregulating electricity market studies for the state of Indiana. Studies also include markets in the Midwest, California, PJM etc., including generation/transmission capacity, pricing, utility finance & risk issues, market oversight, power pool & ISO, reliability/security. The studies also include:

- Developed a Compact DC (CDC) power flow method for quantifying the potential power exchanges between different regions, including ECAR/MAIN under both perfect and imperfect (gaming) competition. Other studies include portfolio studies, option pricing, and their applications to energy markets, and forward price curves for different areas in the Midwest, Northeast, PJM, and California.
- Market power monitoring and mitigation studies for the U.S. electricity markets. Conducted two workshops for regulation agencies.
- Studied reliable and optimal dispatch of bids for deregulated electricity markets.
- Developed spatial gaming models and bidding strategies with applications to deregulated electricity markets and for forward price construction.

97 – 2000: A consultant for the study on technical issues of the Southern and Western African Power Pools, including electricity trade, efficiency-improving contracting, etc.

- Developed a new long/mid-term hydro-thermal scheduling method based on hydro profit maximization. It is for the hydro power owners in a competitive electricity market.
- Developed a new, unconditional hydrothermal generation scheduling method that was rated highly by several utilities in Southern African Power Pool.

96 – 97: Studied energy efficiency and CO2 of China. Emphasis is on motors and industry use.

96 – present: Risk assessment, Monte Carlo simulations for quantifying price distributions. Studied policy issues on emission (CO2 and others) and energy efficiency.

90 – present: Numerous presentations to utilities, state commissions, and other interests groups regarding deregulation and price implications in deregulated energy markets.

9/93 –12/95: Completed an Integrated Resource Planning (IRP) project sponsored jointly by EPRI and the Oklahoma Gas & Electric (OG&E).

1/91 – 5/92: Development of load forecasting models for OG&E and participation in the training of several utilities' forecast professionals.

Summer/90 – Fall/95: Ph.D. study and research asst., School of EE, Univ. of Oklahoma.

- Engaged in the study of network constrained unit scheduling for power markets.
- Improved a Dynamic Programming based generation scheduling method that is 6 times faster than the DPSTC method and usually obtains better solutions.
- Introduced a Level-Crossing based method for controlling electrical appliances. This method would lead to the complete new concept and strategy of controlling.
- Developed a Compensated Box-Jenkins Transfer Function Model and a Temperature Match Based Optimization Model for demand forecasting, etc.

HONORS (selected)

- Outstanding Academic Achievement Award, the University of Oklahoma, 1993 -1994.
- Five academic excellence scholarship awards from the University of Oklahoma.
- Advisor for an award winning student organization at Purdue in 1998.

EDUCATION

Ph.D. of EE (1995), School of EECS specializing in power system engineering and power economics, with a minor in Operations Research, University of Oklahoma, Norman. Major advisor: A.M. Breipohl. Also received MSEE in China.

A REFEREE for the following journals and meetings:
IEEE Transactions, Automatica, IEEE PES Conferences and
International Journal of Electrical Power & Energy Systems, etc.

TECHNICAL CONTRIBUTIONS

Refereed journal papers (selected from a total of 28**):**

1. R. Ivanic, P. Preckel, Z. Yu, "A Market Power Model without Counter Flows and with Losses," Decision Support Systems, special issue on deregulated power market, forth coming Vol. II, 2004.
2. Z. Yu, "A market power model with price caps and DC power flow constraints," International J. of Electrical Power & Energy Systems, Vol. 25 (4), MAY 2003, pp. 301-307.
3. Z. Yu, "An MIP Mean-Variance Method for Energy Market Risk Analysis," Energy Economics, Vol. 25(3), pp 455-468, 2003.
4. Z. Yu, "A Theory on the Existence of a Nash Equilibrium," IEEE Power Engineering Society (PES) Letters, Power Engineering Review, Dec. 2002.
5. Z. Yu, "The Proposed CLP Method for Allocating Real Power Losses of Multiple Flows," IEEE PES Letters, IEEE Power Engineering Review, Vol. 21, No. 11, 2001, pp. 45-47.
6. Z. Yu, P. Preckel, D. Nderitu, F.T. Sparrow, "A Spatial Gaming Model with CO2 Tax and Emission Constraints," Journal of Electrical Power & Energy Systems, Vol. 23 (6), 2001, pp. 451-457.
7. Z. Yu, "A Strategic Coalition Gaming Model with Spatial Formulation for Electricity Markets," IEEE PES letters, IEEE Power Engineering Review, Feb. 2001, pp. 42-44.
8. Z. Yu, F.T. Sparrow, G. Nderitu, "A Market Power Monitoring Model for the Restructured Electricity Markets," IEEE PES Letters, IEEE Power Engineering Review, July 2000.
9. Z. Yu,"A Mixed Integer Social Welfare Maximization Model and Optimal Electricity Pricing," IEEE PES letters, IEEE Power Engineering Review, July 1999.
10. Z. Yu, F.T. Sparrow, B.H. Bowen, "A New Long-Term Hydro Production Scheduling Method for Maximizing the Profit of Hydroelectric Systems," IEEE Trans. on Power Systems, Feb. 1998.
11. Z. Yu, A.M. Breipohl, F.N. Lee and R. Adapa, "The Extension of an Analytical Method for Comparing Natural Diversity to DSM Controlled Diversity," IEEE Transactions on Power Systems, Vol.11, No. 4, Nov. 1996.
12. Z. Yu, A.M. Breipohl, F.N. Lee, "A Comment on the Probability Distribution of Continuous Level-Crossing A/C Load Processes," IEEE Trans. on PWRS, Vol. 11(3), 1996.
13. Z. Yu, A.M. Breipohl, F.N. Lee and R. Adapa, "An Analytical Method for Comparing Natural Diversity to DSM Controlled Diversity," IEEE Trans. on PWRS, Vol.11, No. 3, August 1996.
14. Z. Yu, "A Temperature Match Based Optimization Method for Daily Load Forecasting Considering DLC Effect," IEEE Trans. on Power Systems, Vol.11, No. 2, May 1996.

Refereed conference papers (selected from a total of 20**):**

1 Z. Yu, et al, "A Probabilistic Thermal Unit Maintenance Scheduling with Probability Space Reduction," accepted in proc. IEEE/PES General Meeting 2004.
2 R. Ivanic, P. Preckel, Z. Yu, "A Stochastic Oligopoly Model for Market Power and Welfare Effects Modeling with Transmission and Losses," Proc. IASTED International Conference, Spain 2003.
3 Z. Yu, "Integrated Risk Management under Deregulation," Proc. IEEE PES Summer Meeting 2002, Chicago.
4 Z. Yu, "Spatial Energy Market Risk Analysis Part I: An Introduction to Downside Risk Measures," Proc. IEEE PES Minter Meeting, Jan. 2002, New York.
5 Z. Yu, "Spatial Energy Market Risk Analysis Part II: The Spatial Risk Model," Proc. IEEE PES Minter Meeting, 2002, New York.
6 Z. Yu, F.T. Sparrow, Doug Gotham, et al., "The Impact of Transmission on Imperfect Competition," Proc. IEEE PES Minter Meeting, 2002, New York.
7 Z. Yu, F.T. Sparrow, D. Nderitu, D. Gotham, F. Holland, "A Large Spatial Gaming Model for the Midwest

Other conference papers (a total of 25):

Reports (selected from a total of 18)

1. Staff Report, "Reliability & Safety Constrained Hydrothermal Scheduling Models for the Pacific Northwest," prepared for the National Infrastructure Simulation & Analysis Center (NISAC), Sandia, July 2003.
2. Staff Report, "A Natural Gas Modeling System for the Midwest and the Northeast". A Technical Report to the Indiana Utilities Regulatory Commission (IURC), Oct. 2003.
3. Staff Report, "The 2001 Indiana Electricity Projections," final report for the Indiana Utility Regulatory Commission (IURC), Oct. 2001.
4. Staff Report, "The 2000 Interim Report on Imperfect Competition of Deregulated Markets," prepared for IURC, Nov. 2000.
5. Staff Report, "The 1999 Indiana Electricity Projections," final report prepared for IURC, Oct. 1999.
6. F.T Sparrow, Z. Yu, B.H. Bowen, W. Masters, "Phase I Report on the Long-Term Generation and Transmission Expansion Planning Models for the Southern African Power Pool," prepared for the Southern African Power Pool, Feb. 1999.
7. Staff Report, "The Projected Impact of Restructuring on Indiana Electricity Prices: An Interim Report," for IURC, May 1998.
8. F.T. Sparrow, Z. Yu, B. Bowen, W. Masters, "Modeling Short-Term Electricity Trade in Southern Africa Power Pool," final report to the Southern Africa Power Pool, Jan. 1998.

Appendix 4D

LIHUA YU

Potter Engineering Center, Room 334
500 Central Drive, Purdue University
West Lafayette, IN 47907
Phone: 765-4949885 Email: yu46@purdue.edu

EDUCATION

1. Ph.D. in Systems and Industrial Engineering 08/2000-03/2004 University of Arizona, Tucson, AZ
2. M.S. in Systems Engineering 08/2000-05/2002 University of Arizona, Tucson, AZ
3. B.S. in Industrial and Management Engineering 09/1991 - 06/1995 Nanjing University of Aeronautics and Astronautics, Nanjing, China.

EXPERIENCE

Research Associate State Utility Forecasting Group, Purdue University, 03/04-Present

1. Natural gas storage and transmission optimization.
2. Natural gas portfolio benchmarking.
3. ASIAN power pool development modeling.

Intern Pinnacle West Capital Corp 11/2002-08/2003

1. Long-term electricity load forecasting analysis and simulation
2. Power spot/forward price forecasting analysis.
3. Value at Risk analysis for power portfolio.
4. Energy data gathering and processing automation.

Research Assistant University of Arizona, Tucson, AZ 08/2000-03/2004

1. Proposed a stochastic optimization approach to power portfolio optimization in deregulated electricity markets.
2. Proposed an algorithm for multistage stochastic programming with multiple time-scales
3. Developed a distributed computing system for large-scale stochastic optimization problems.

PUBLICATIONS

1. S. Sen, Lihua Yu, and Talat Genc. A Stochastic Programming Approach to Power Portfolio Optimization. (accepted by Operations Research)
2. Lihua Yu, and Lewis Natimo. Distributed Computing System for Multi-stage Stochastic Programmings. Proceedings of 2004 Industrial Engineering Annual Conference.
3. Lewis Natimo, and Lihua Yu. Distributed Discrete Optimization under Uncertainty. Proceedings of 2004 Industrial Engineering Annual Conference.
4. S. Sen, Lihua Yu, and Talat Genc. Decision Aids for Scheduling and Hedging (DASH) in Deregulated Electricity Markets: A Stochastic Programming Approach to Power Portfolio Optimization. Proceedings of 2002 Winter Simulation Conference.
5. Lihua Yu, and S. Sen. A Column Generation Based Parallel Computing System for Multi-stage Stochastic Programs. Presentation Abstract in 2003 INFORMS Conference.
6. Lihua Yu. A Stochastic Optimization Approach to Power Portfolio Optimization and A Nested Column Generation Decomposition Strategy. Presentation Abstract in 2002 INFORMS Conference.
7. Tongshui Wu, and Lihua Yu. Optimal Scheduling Model of Hub and Spokes Route Network. Journal of Nanjing University of Aeronautics and Astronautics 31(4). Nanjing, 08/1999. (in Chinese)
8. Tongshui Wu, and Lihua Yu. Airline Network Resource Optimization. Proceedings of 2000 Civil Aviation Research Conference. (in Chinese)

ACADEMIC ACTIVITIES

1. Member of Institute for Industrial Engineering. (IIE)
2. Member of Institute for Operations Research and the Management Sciences (INFORMS).
3. Session Co-Chair in 2004 Industrial Engineering Annual Conference.

Appendix 4E

VEERADECH SIRIARIYAPORN

Contact data: siriariy@purdue.edu, veeradech@yahoo.com, http://veeradech.8k.com
2400 Northwestern #33, West Lafayette, IN 47906,
Mobile: 765-409-2862

Areas of Interest

- **Professional Interest:** Energy Management, Risk and Portfolio Analyses, Decision Science, and Production Planning
- **Academic Interest:** Power System Engineering, Engineering Economics, and Operations Research

Education

August 2001 – Present *Purdue University* *West Lafayette, IN*
Doctor of Philosophy (Ph.D. Candidate in Industrial Engineering)
- Major: Engineering Economics and Optimization
- Dissertation: Reducing the Cost of Uncertainty in Serving Highly Varying Loads with Supply Contracts

August 1999 – August 2001 *Purdue University* *West Lafayette, IN*
Master of Science in Electrical and Computer Engineering
- Major: Energy Sources and Systems
- Master's Thesis: Determining the Cost of the Regulation Ancillary Service in the Presence of Highly Varying Loads
- GPA: 3.50/4.00

June 1994 – March 1998 *Kasetsart University* *Bangkok, Thailand*
Bachelor of Engineering in Electrical Engineering (Second Class Honors)
- Major: Power System
- GPA: 3.28/4.00

Non-Degree Education

July 13-27, 2004 *Midwest Independent System Operator* *Carmel, IN*
Training Program: Midwest Electricity Market Implementation
- Midwest Market 101-102: Fundamental Concepts of Electricity Market Structure, Commercial Model Configuration, Locational Marginal Pricing, Day-Ahead and Real-Time Markets, Financial Transmission Rights, Bids and Offers, Physical and Financial Scheduling, and Market Settlements
- Market Scenarios Workshop: Market Instrument Usage, Security Constrained Unit Commitment, and Security Constrained Economic Dispatch

October 8-10, 2003 *Indiana Utility Regulatory Commission* *Indianapolis, IN*
Training Program: Portfolio Optimization and Risk Management
- Conducted by State Utility Forecasting Group, Purdue University
- An Introductory Course to Financial Derivatives, Option Pricing, Theory of Portfolio and Risk, and Stochastic Programming for Optimization under Uncertainty

May 28, 2003 – June 10, 2003 *Purdue University* *West Lafayette, IN*
Mini MBA Program: Applied Management Principles (AMP)
- Awarded/Certified by Krannert School of Management and School of Industrial Engineering, Purdue University
- Equivalent 3 Credit Hours with Coverage on Accounting, Human Resource Management, Financial Management, Marketing Management, Strategic Management, and Entrepreneurship

January 1999 – June 1999 *Drexel University* *Philadelphia, PA*
Intensive English Program

Work Experiences

August 2001 – Present *Purdue University* *West Lafayette, IN*
Research Assistantship (School of Industrial Engineering)
Ph.D. Thesis supported by DOE/NiSource
- Analyzing the impacts of highly varying customer demand in terms of costs to electric utilities
- Designing supply contracts to mitigate risks from demand uncertainty and price volatility
- Modeling methodologies via portfolio approach and stochastic programming for electricity production planning

Distributed Generation Project supported by DOE/NiSource
- Investigating economic benefit from integration system of distributed resources
- Identifying factors from integration which affect the distribution system in terms of protection, quality, and reliability
- Modeling a decision procedure for investment of distributed generation systems

January 2000 – August 2001 *Purdue University* *West Lafayette, IN*
Research Assistantship (School of Electrical and Computer Engineering)
Master's Thesis supported by DOE/NiSource
- Investigating financial aspects of automatic generation control, economic dispatch, and unit commitment
- Modeling methodologies to determine the costs associated with the regulation ancillary service

June 1997 – March 1998 *Kasetsart University* *Bangkok, Thailand*
Senior Project
- Designing a cost estimation program, written in Delphi, to calculate power system cost of building/factory project

March 1997 – May 1997 *ABB (Thailand) Limited* *Bangkok, Thailand*
Internship
- Assisting in production planning in Production Division, Switchgear Business
- Monitoring the efficiency of manufacturing process to achieve ISO 9002

Thesis and Publications

Master's Thesis
- V. Siriariyaporn, "Determining the Cost of the Regulation Ancillary Service in the Presence of Highly Varying Loads," Master of Science in Electrical and Computer Engineering Thesis, August 2001. Advisor: F.T. Sparrow.

Conference Proceedings
- V. Siriariyaporn, D.J. Gotham, and F.T. Sparrow, "Determining the Incremental Cost to Electric Utilities in Serving Highly Varying Loads," *The 2nd International Conference on Electric Utility Deregulation, Restructuring, and Power Technologies*, April 5-8, 2004, Hong Kong.

- V. Siriariyaporn, D.J. Gotham, R.A. Kramer, and F.T. Sparrow, "Measuring the Cost of Providing the Regulation Ancillary Service with Highly Varying Loads," *The Proceedings of the 34th Annual North American Power Symposium*, October 14-15, 2002, Arizona State University, Tempe, AZ, pp. 427-434.

Technical Reports

- D.J. Gotham, F.T. Sparrow, D.G. Nderitu, and V. Siriariyaporn, Final Report of the Project "The Economic Impact of Integrating Multiple Distributed Generators into Modern Distribution Systems," Prepared for the U.S. Department of Energy and NiSource Energy Technologies, December 2003.
- D.J. Gotham, F.T. Sparrow, and V. Siriariyaporn, Final Report of the Project "Enhancing the Operation of Highly Varying Loads to Increase Electric Reliability, Quality, and Economics," Prepared for the U.S. Department of Energy and NiSource Energy Technologies, December 2002.
- D.J. Gotham, F.T. Sparrow, V. Siriariyaporn, and D.G. Nderitu, Status Report for Year 2 of the Project "Enhancing the Operation of Highly Varying Loads to Increase Electric Reliability, Quality, and Economics," Prepared for the U.S. Department of Energy and Northern Indiana Public Service Company, January 2002.
- D.J. Gotham, F.T. Sparrow, and V. Siriariyaporn, Status Report for Year 1 of the Project "Enhancing the Operation of Highly Varying Loads to Increase Electric Reliability, Quality, and Economics," Prepared for the U.S. Department of Energy and Northern Indiana Public Service Company, January 2001.

Courses of Interest and Special Competence

- **Electrical Engineering:** Electric Machinery, Power System Analysis, High-Voltage Engineering, Power Systems in Buildings, Energy Conversion, Computational Methods for Power System Analysis, and Model & Simulation for Power System Components
- **Industrial Engineering:** Systems Simulation, Design & Control of Modern Production Systems, and Human Factors in Engineering
- **Mathematics and Optimization:** Advanced Mathematics for Engineers and Physicists, Linear Algebra, Linear Programming, Heuristic Optimization, and Optimization Methods for Systems & Control
- **Finance:** Financial Engineering, and Intermediate Financial Theory
- **Economics:** Fundamentals of Applied Welfare Economics, Benefit/Cost Analysis, Engineering Economic Analysis, Economic Decisions in Engineering, and Advanced Decision Theory

Professional Memberships

- Associate Engineer of the Office of the Board for the Control of the Engineering and Architecture Profession (Thailand) since 1998
- Student Member of the Institute of Electrical and Electronics Engineers (IEEE) since 1999

Computer and Programming Skills

- Operating Systems: DOS, Unix, and Windows
- Languages: Assembly, AutoMod, Delphi, GAMS, HTML, Matlab/Simulink, and Pascal
- Application Programs: Microsoft Office, @Risk, Microsoft Frontpage, and Adobe PhotoShop

Extracurricular Activities

April 1998

- Visiting a production line of ABB Sace S.p.A., a low-voltage system company, in Bergamo, Italy

February 1998

- Attending public relations for Kasetsart University Engineering Academic Exhibition 1998, in Bangkok, Thailand

April 1997

- Visiting a production line of Scame S.p.A., an electrical equipment company, in Parre, Italy

March 1995 – April 1995

- Participating in Overseas Chinese Youth Language and Culture Conference, in Taipei, Taiwan

April 1992

Visiting Hannover Messe 1992, a world exhibition of technology and automation, in Hannover, Germa