An Insight into Power System Operation and Load Forecasting in AlbertA

CAPSTONE PROJECT REPORT
POWER SYSTEM APPLIED COURSE, SAIT ALBERTA
DECEMBER 2017

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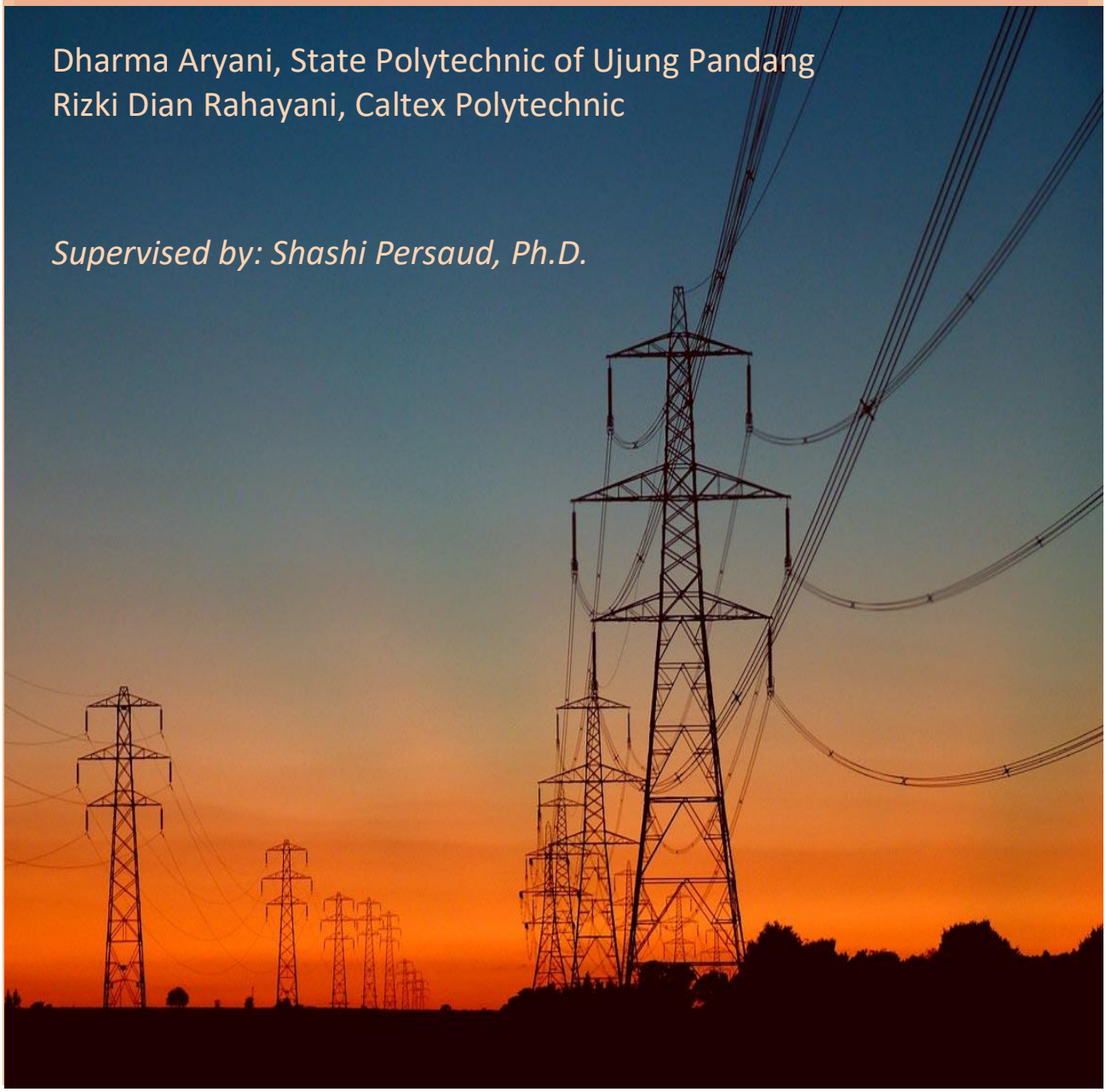

Executive Summary

In 1996, Alberta began to restructure its electricity market away from traditional regulation to a market-based system. Nowadays, the power system operations are comprehensively managed by the respective authorities to implement reasonable approach for planning and operating the electricity system in order to meet the needs and demand of electricity in Alberta. The market scheme includes a host of buyers and sellers, and an increasingly diverse infrastructure. In the distribution side, consumers range from residential buyers to huge industrial consumers.

Alberta Electric System Operator manages and coordinates operation of the power grid and makes sure that the supply of power is in constant balance with the demand for power across the province of Alberta, plans the provincial transmission system including all of its interties with neighboring provinces, and operates Alberta's wholesale electricity market based on the supply and demand forecasting.

In power system, the forecasting of electrical demand and supply are estimated based on the prediction models. The electricity demand forecasting is very important to evaluate and to analyze the planning of production, transmission, and distribution capacities. A key factor affecting electricity demand in Alberta over the long term is economic growth. Alberta's economy is highly correlated with oil prices due to the size of its oil industry, especially the oilsands. In Alberta, AESO need the forecasting results to formulate and design the Reference Case, Scenario Load Peak, and the estimated installed generation by all type in the future years.

This project is aimed to learn about the power system industry structure in Alberta and to conduct a study for the load forecasting management system. In the future, the outcomes of this project will be very valuable as references for study and investigation in Indonesia's electricity operational and market regulation system.

I. Introduction

It has been two decades since Alberta electricity system has been restructured from regulated to deregulated operational system. This transformation leads to a more reliable and sustainable power system with a more diverse power generation infrastructures. Nowadays, the power system operations are comprehensively managed by the respective authorities to implement reasonable approach for planning and operating the electricity system in order to meet the needs and demand of electricity in Alberta [1].

In electricity load management, a sufficient knowledge of load profile is very essential for designing the range of tariff rates which are in line with efficient revenue generation [2]. The classification of customer load demand profiles is also the basis for daily load shapes identification and optimum usage prediction of the available electricity supplies [3]. Furthermore, electricity load profile can provide distinctive information for advanced tasks such as forecasting, balancing of energy loads, monitoring and optimization of consumptions.

Another important element in electricity load management that has received more attention in any regions is the load forecasting. The error of electricity load forecasting may increase the operating cost since an overestimation of future load results in excess supply. In other way, underestimation of load leads to a failure in providing enough reserve and implies high costs in peaking unit. Adequate electric production requires each member of the global cooperation being able to forecast its demands accurately. However, load forecasting is a complex task that is highly correlated with many influencing factors, such as climate or seasonal factors and social conditions [4].

This project report is organized into five sections. Section I presents the project scope followed by a summarized description of Alberta power system operation in Section II. The market system structure of power system in Alberta is illustrated in Section III, and the forecasting system of demand and supply are highlighted in Section IV. A conclusion of the project is provided in Section V.

II. Overview of Alberta Power System Operation

Electricity is the facilitator of growth and development in the energy sector and all other sectors of the economy. As the economy and population continues to grow, significant capacity additions in electrical power generation will be needed. There are three elements in power system, namely: generation, transmission and distribution [7]. Figure 1 shows the functional organization of the elements.

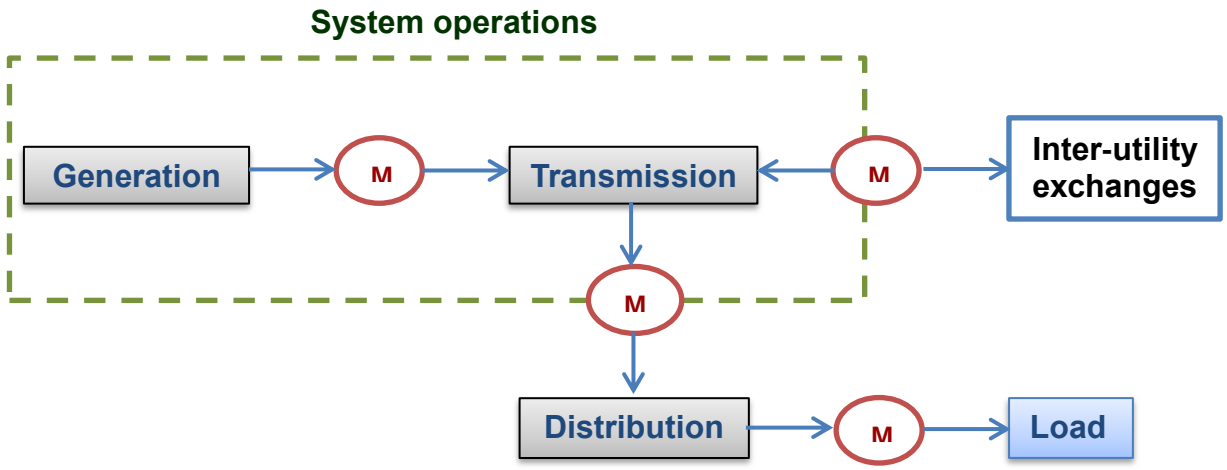

Figure 1. Functional Structure of Electricity System

II.1. System Operation

The Alberta Interconnected Electric System (AIES), the transmission system network for Alberta province, is planned and operated by the Alberta Electric System Operator (AESO). The network manages high-voltage transmission lines, towers and equipment to carry electricity from generators to large industrial customers as well as low-voltage systems that distribute it to cities, towns and rural areas [1]. In details, AESO manages and coordinates operation of the power grid and makes sure that the supply of power is in constant balance with the demand for power across the province, plans the provincial transmission system including all of its interties with neighboring provinces, and operates Alberta's wholesale electricity market with 200

participants and about $7 billion dollars in annual energy transactions, efficient and openly competitive market for all participants.

The electricity network in Alberta stretches for 26,000 km, covering an area of 660,000 Km^2. A total of 235 generating units spread throughout Alberta can generate 16,423 MW of power. The highest power demand in Alberta until January 2017, amounting to 11,458 MW and that number will continue to increase in line with the rising incomes, technology and lifestyles that will encourage greater power consumption. Since 2000 the electricity demand in Alberta has increased by 28%. Currently, the demand for electric energy in Alberta, the largest is still in the coal fired power plant with a percentage of 38.61%, the rest is produced by cogeneration, combined cycle, wind, simple cycle, hydro and other energy sources [1]. The complete power generated for each power plant is shown by the following figure.

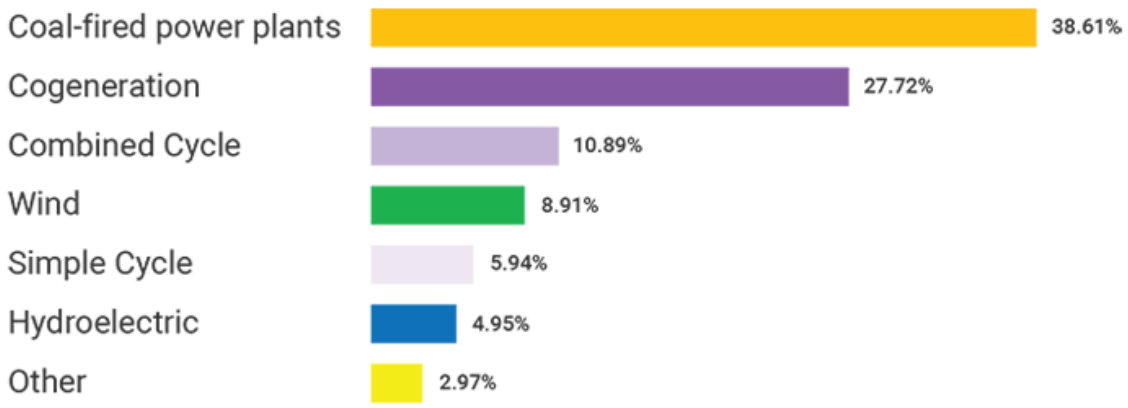

Figure 2. Power Generation in Alberta [1]

Electricity is produced in real time as customers demand it. Since demand fluctuates, it is continually reviewed and anticipated to ensure enough power is steadily available to meet the needs of consumers. The Alberta Internal Load for the past four years are shown in Figure 3.

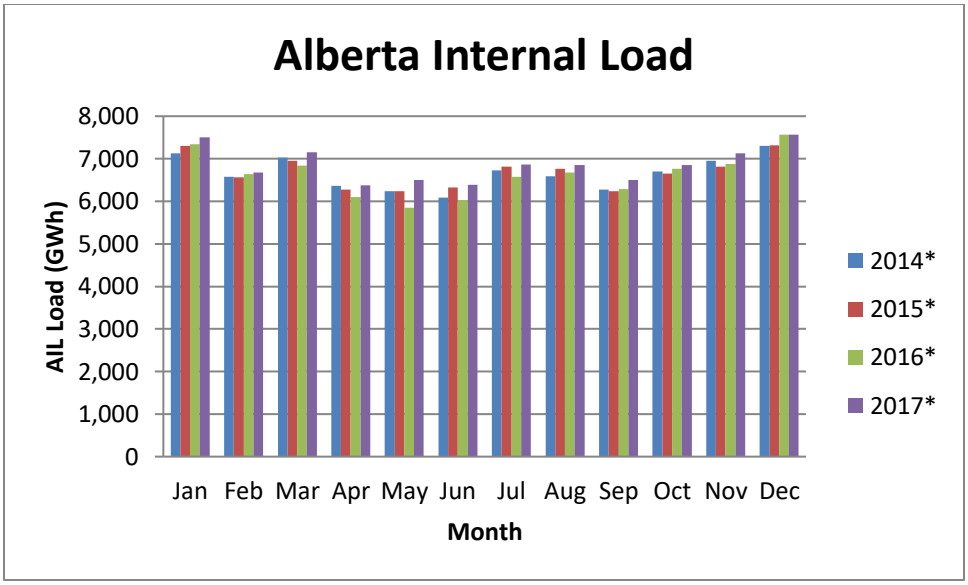

Figure 3. Monthly Alberta Internal Load 2014-2017

II.2. Classification of Electricity Customers

The consumers of electricity in Alberta are categorized into four classes; Residential, Farm, Commercial and Industrial. Detail data of electricity consumption and the number of customers in each customer class are provided in Alberta Energy Regulator report. A description of the data of total annual sales (in GWh) and number of customers by market segment from 1985 to 2016 and the lists of monthly sales (in GWh) and number of customers by market segment from 2012-2016 can be found in [9]. In order to provide a brief overview of the sales and the number of customers, the historical data are transformed into graphs of Figure 4 and Figure 5.

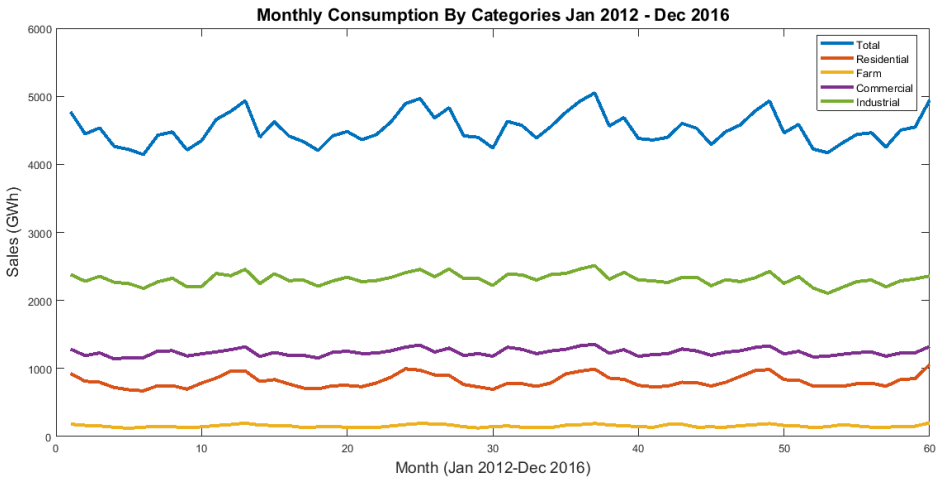

Figure 4. Monthly Consumption from January 2012 to December 2016

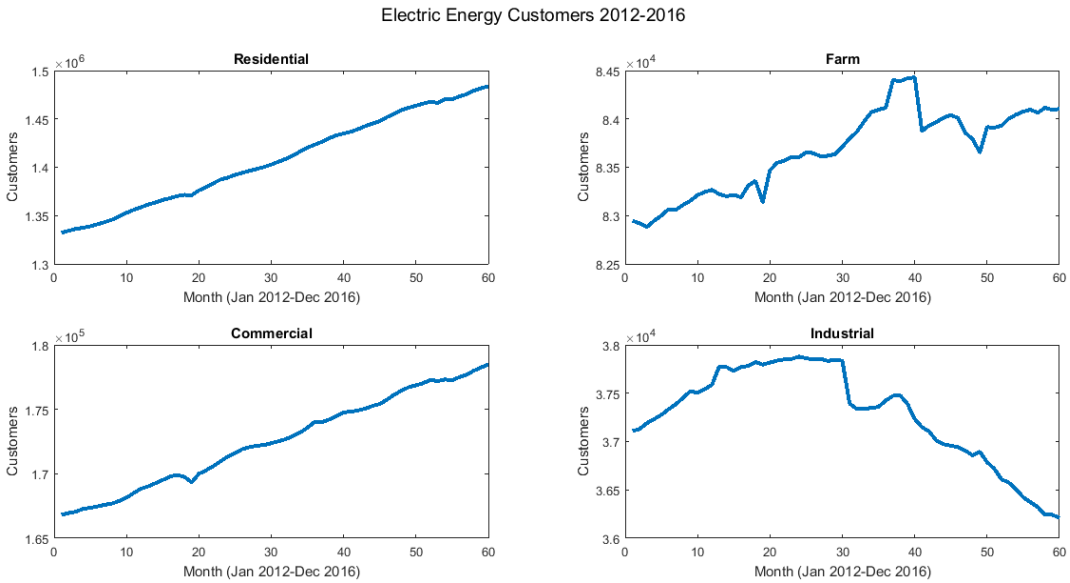

Figure 5. Number of Customers from January 2012 to December 2016

III. Electricity Market System

In Alberta, electricity is generated, sold and bought on the wholesale electricity market. The Alberta Electric System Operator (AESO) plays an instrumental role in developing and operating this market [1]. The power pool is operated by Alberta's Independent System Operator (ISO)

whose company name is Alberta Electric System Operator (AESO). AESO is independent and non-profit organization that operates power pool and holds responsibilities to control the dispatch of all electric power generation in Alberta, scheduling the energy flow on the interconnections and monitoring the Alberta's electricity network. In wholesale trading, AESO operates the Energy Trading System. Besides AESO in industry structure of EUA, there is also balancing pool as an independent agency in charge to manage certain assets, liabilities, revenues and expenses arising from the transition to competition in Alberta's electric industry (22).

III.1. Deregulated Power Industry

The history of de-regulation of power industry in Alberta is described in Figure 6.

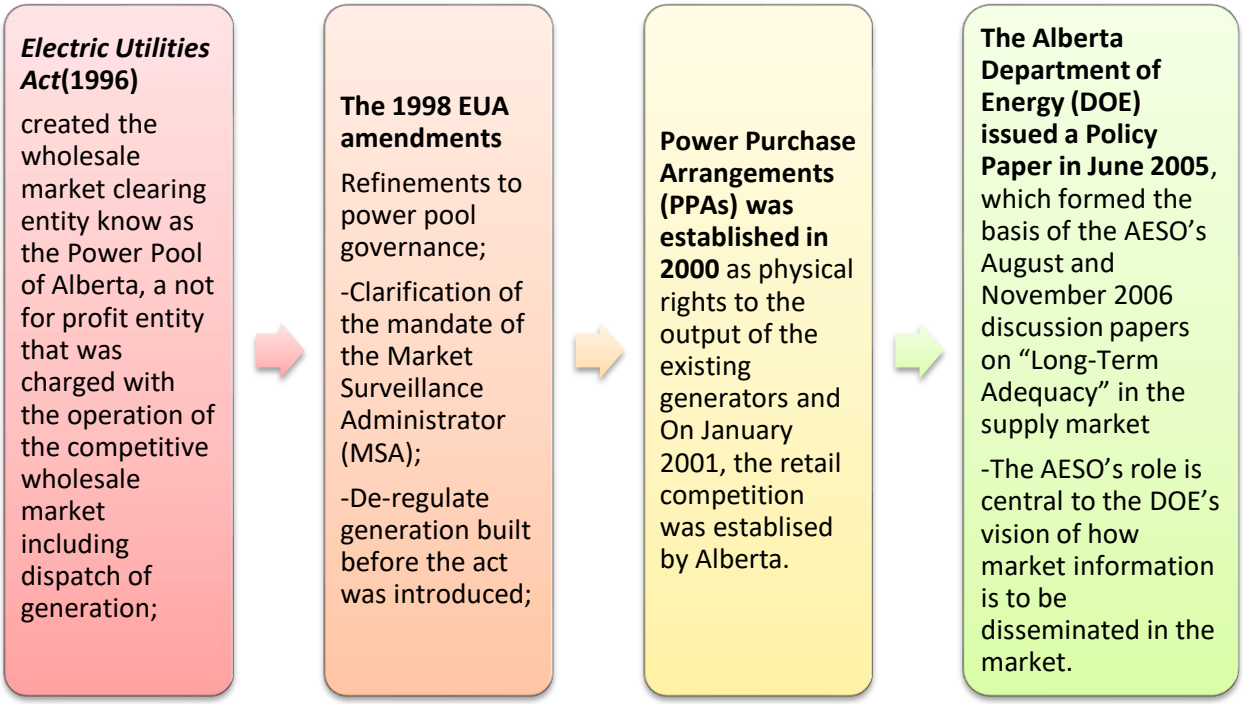

Figure 6. Transition to Deregulation System

Before 1995, the power plant and transmission in the Province of Alberta were still monopolized by three private companies; TransAlta Utilities (TAU) in South, Alberta Power Ltd (APL) in Central Alberta and Edmonton Power (EP) in the North. Then began in 1995, slowly, through the Electric Utilities Act (EUA), the Alberta government announced a competitive

marketplace for the wholesale trading of electricity. The Transmission Administration (TA), as an independent agency, serves as the coordinator in the operation of the power grid, regulates the transmission process in real time and ensures the support services system is working properly. The year of 1995 will be the forerunner to deregulation era. Where regulation of single buyer, controlling price, restricting entry of competitors into the electricity markets and monopoly of the three large companies are removed and the implementation of open market competition is established.

In 1996, the process of transition of Alberta electricity from single buyer into wholesale competition is implemented by controlling the interconnection area between generating and transmission that is known as a control area or power pool. The power pool is a wholesale market for generators and retails/loads trade electricity [14]. In the implementation of power pool system, market surveillance administrator (MSA) is authorized to protect customer interests in market place. Main MSA responsibility is monitoring Alberta'electricity and retail natural gas market to ensure that they operate in a fair, efficient and openly competitive manner [15]. MSA also mandate to make surveillance and investigation of electricity market place, overseeing market performance, market participant behaviour and conduct, including the conduct of ISO and balancing pool. The industry structure of EUA in Alberta shown in Fig. 7.

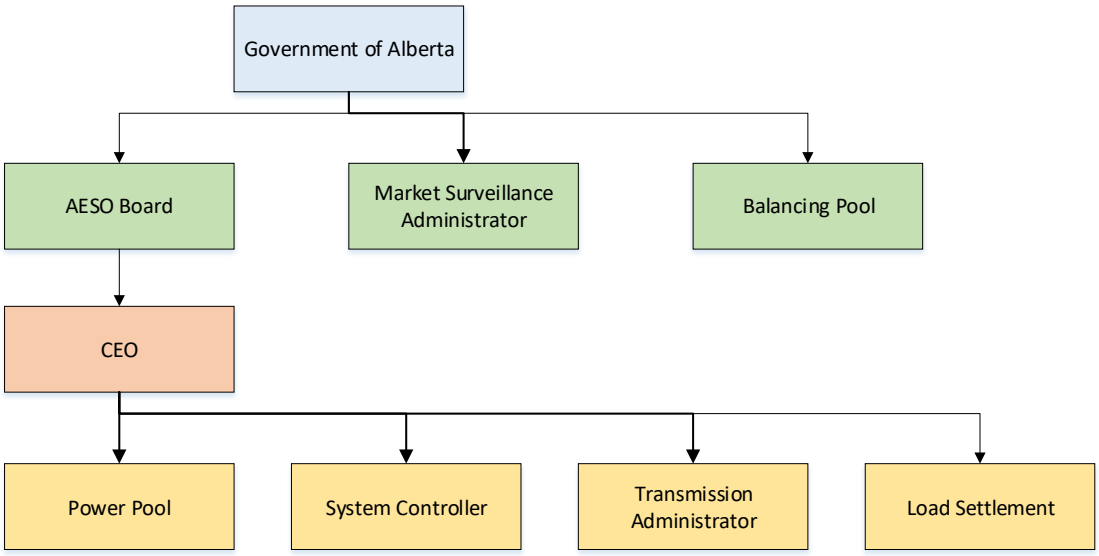

Figure 7. Industry Structure of EUA [14]

III.2. Wholesale and Retail Competition

On wholesale systems, all parties engaged in the buying and selling of electricity, as well as the management and operation of the power pool. Sellers and buyers have non-discriminatory access to the pool, but they must meet the qualifications set out by the EUA and the power pool. The flowchart of the buyers and sellers pooling process in wholesale is shown in Figure 8.

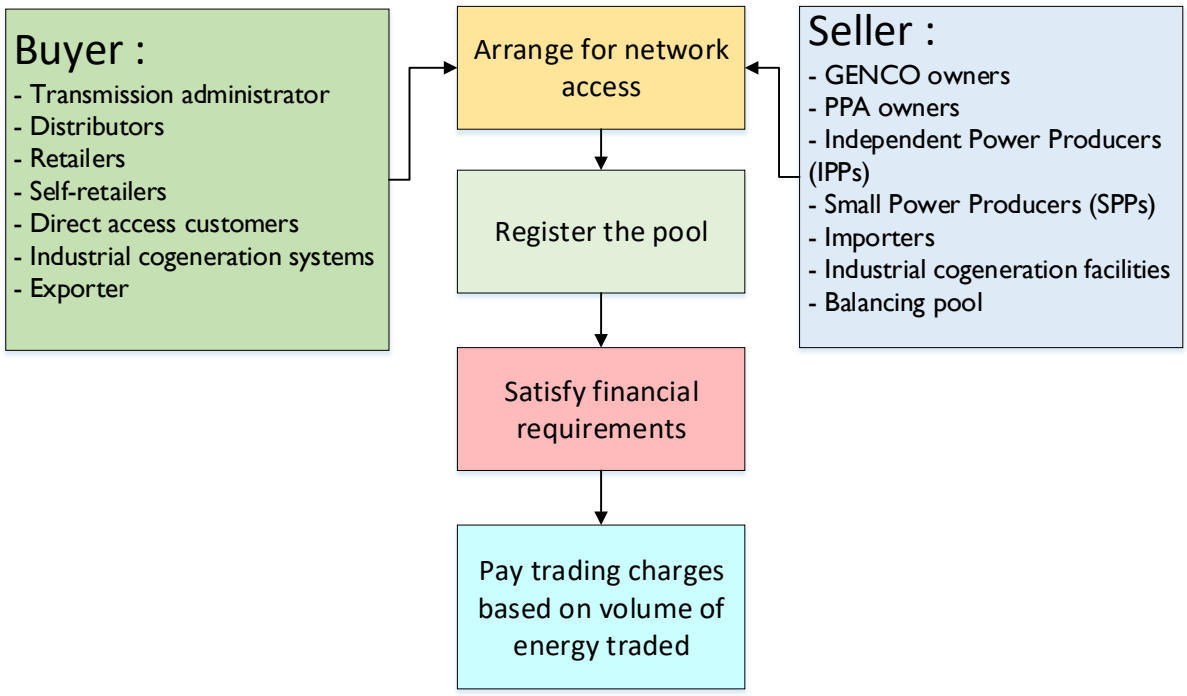

Figure 8. Pooling Process

The hourly price of electricity in the pooling process is determined by the pool administrator based on amount of bids from buyers and amount of offer from sellers. The hourly price known as spot market. In pool system, before 12 pm each day, seller offers the supply of blocks of energy at a fixed prices and buyer offer the disconnection of load if pool price exceeds a certain threshold level. After pool administrator receives bids and offers by noon of each day, then pool administrator ranks offers and establishes a merit order, predicts next day and week-ahead prices, prepare the day and week ahead schedules for generators, bids, imports and exports and every 4:00 pm releases a general forecast schedule to the public and specific unit schedules to each participant.

An effective wholesale market leads to the best allocation of resources, the greatest material progress, and the highest quality with lowest prices of utility. When the retail is extended is extended to supply, the final consumers are free to choose suppliers since the consumer prices are unregulated, and generators can sell to any party. Furthermore, the link between consumers and suppliers are based on economics not in monopoly system. A complete wholesale process to the distribution of electricity to the consumer is shown in Figure 9.

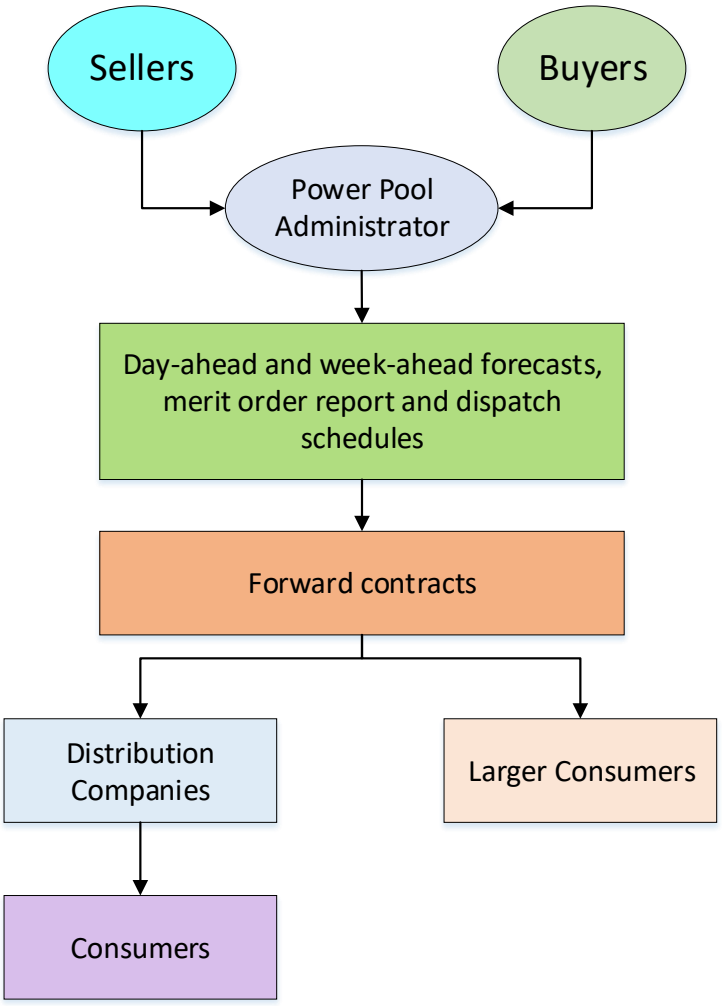

Figure 9. Wholesale Market Process

Retailing is the sale of electricity to final consumers which includes procurement, pricing, sale, billing and payment. It is performed by separate retail entities and opens to competition since the consumers are free to choose from among the available retailers.

As can be seen from Figure 10, the retailing system is established based on three agreements. A Connection Agreement that is enlisted between consumer and wire service provider which covers the physical connection for delivery of electricity. A Supply Agreement is agreed by the consumer and retailer for the sets out prices, contract period and other terms of supply. A Use of System Agreement is made between retailer and wire service provider that allows the retailer to use the distribution network, then retailer must agree to pay volume (MWh) distribution charges at the regulated rate and the wire owner may provide meter readings [16].

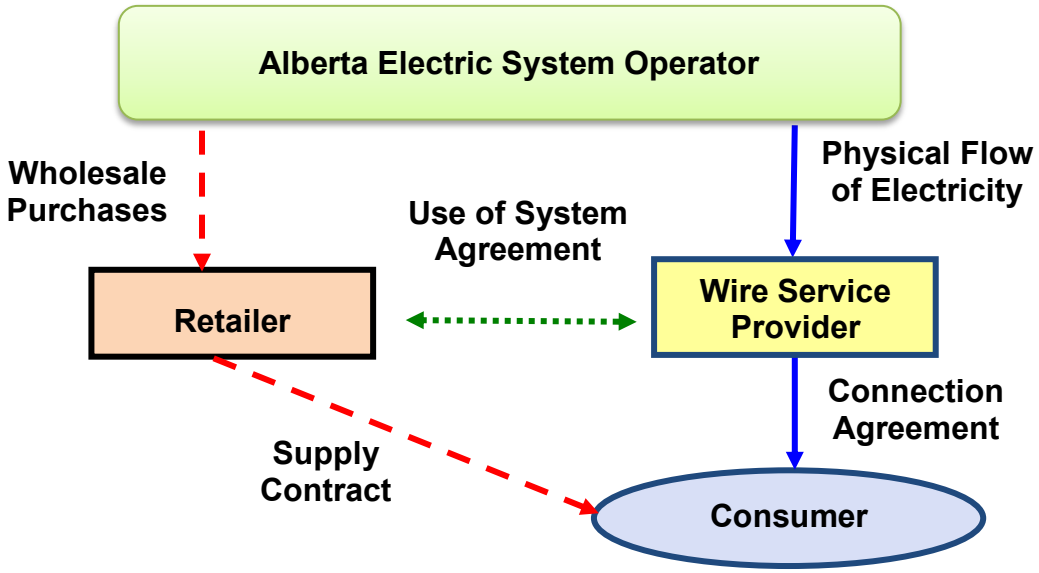

Figure 10. Retail Market

The deregulated charges for the electricity consumption in the real market are composed by several types of charge which are illustrated in a block structure of Figure 11.

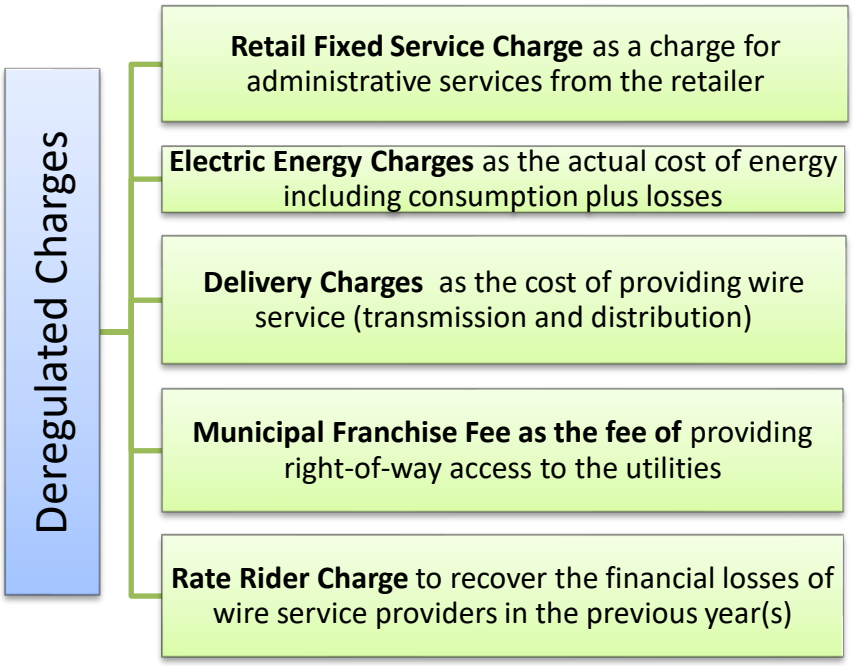

Figure 11. Charges in Deregulated System

IV. Demand and Supply Forecasting

Forecasting can be defined as a mechanism to determine the direction of future trends by utilizing the historical data. In power system, the forecasting of electrical demand and supply are estimated based on the prediction models. The electricity demand forecasting is very important to evaluate and to analyze the planning of production, transmission, and distribution capacities [10]. Load forecasts are extremely important for energy suppliers, ISOs, financial institutions, and other participants in electric energy generation, transmission, distribution, and markets [11].

IV.1. Forecasting Method

Over the last few decades a number of forecasting methods have been developed. The development, improvements, and investigation of the appropriate mathematical tools will lead to the development of more accurate load forecasting techniques. Load forecasts can be divided into three categories: short-term forecasts which are usually from one hour to one

week, medium forecasts which are usually from a week to a year, and long-term forecasts which are longer than a year. The AESO publishes a *Long-term Outlook* every two years with updates as necessary. It is our forecast for electricity demand and generation in the province looking out 20 years. This report is compiled to share information about the long-term transmission plans and regulatory filings based on the historical data and forecasting approaches [1].

The forecasting outlook data are generated using variety of inputs including third-party forecasts and the most up-to-date data available. Any forecasting results should provide information about the expected growth in electricity demand, the anticipated demand for generation capacity, the potential types and locations of new generation [1].

Different techniques have been implemented for forecasting the supply and demand in Alberta energy system that are listed as follows:

- Neural Network Models to be continually assessed against actual values and the models are periodically reviewed by third-party expert
- Econometric Models to be annually assessed against actual values and the models are reviewed every 2nd year by third-party expert
- Hourly substation forecast is a 20-year hourly forecast by substation incorporating utility substation forecast information
- Capacity Generation Model to test the adequacy and fuel/technology mix
- Market evaluation tool is probabilistic approach to asses bidding and generation behavior and to give the economics and physical characteristic of supply and demand.

IV.2. Forecasting Results

Final results of forecasting tools:

- 20 years hourly load forecast by substation based on models drive by historical information of electricity and economy relationship

- 20-year forecast of generation additions based on fundamentals of generation costs, demand growth, policies and technology drivers
- Load and generation scenarios to address uncertainty on largest driver of change

The forecasting solutions are grouped based on the period of prediction.

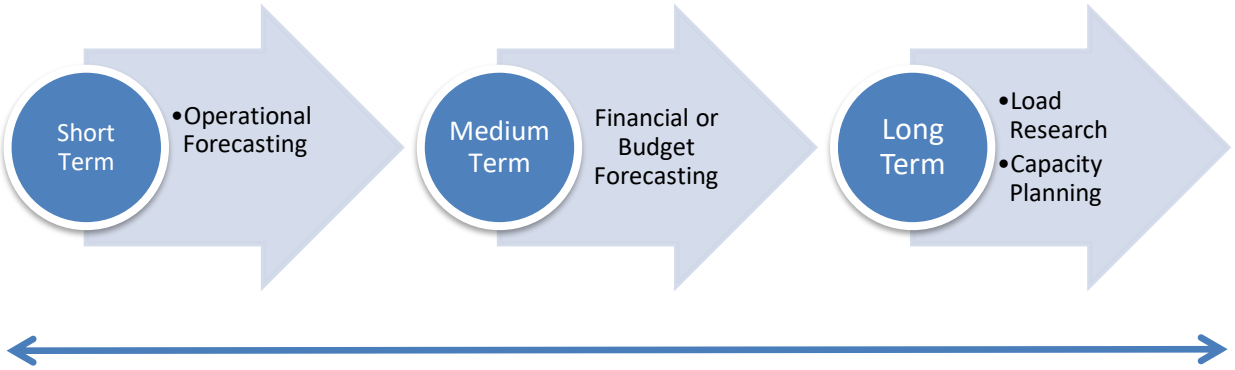

Figure 12. Forecasting Term and Output Solutions

A key factor affecting electricity demand in Alberta over the long term is economic growth. Alberta's economy is highly correlated with oil prices due to the size of its oil industry, especially the oilsands. The reduced oil price outlook and resulting modest pace of anticipated oilsands development impacts the overall Alberta economy [5]. The supply and demand of electricity in Alberta are illustrated in Figure 13 based on actual values in the past 10 years (2006-2016) and the predicted values until 2030.

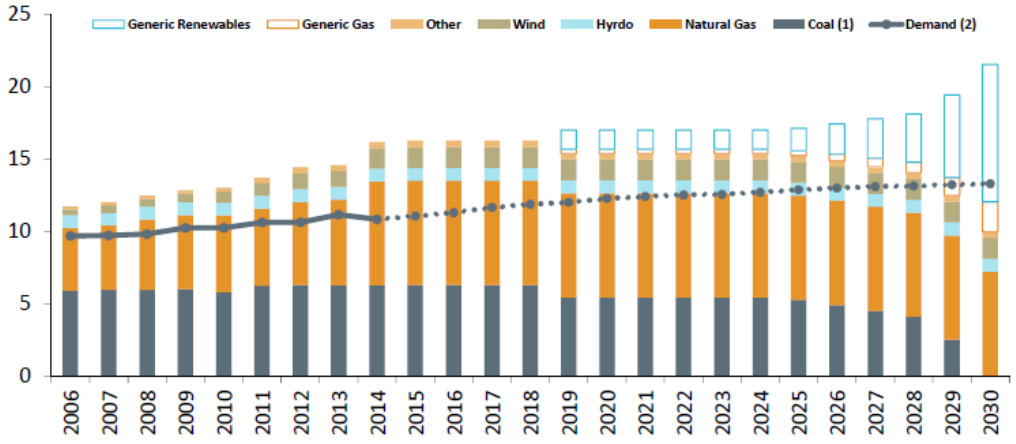

Figure 13. Alberta Supply and Demand [6]

IV.3. Utilization of forecasting results

Load forecasting is a vital element in electricity utility to support important decisions on purchasing and generating electric power and infrastructure development [12]. The objectives of forecasting are:

- To anticipate future demand for electricity generation capacity
- To make assumption about future load growth
- To support market system of electricity system

In Alberta, AESO need the forecasting results to formulate and design the Reference Case, Scenario Load Peak, and the estimated installed generation by all type in the future years. The example of the design is provided in the table below:

Reference Case and Scenario Load Peak and Installed Generation by Type (MW) (Data from AESO Long Term Outlook 2017) [5]

2022		Reference Case	Low Growth	High Coal-to-Gas	No Coal-to-Gas	Large-hydro Addition	Western Integration	High Cogeneration
Demand	**AIL Peak**	12,260	11,847	12,260	12,260	12,260	12,260	12,260
Generation	**Coal-fired**	3,849	3,849	3,849	5,430	3,849	3,849	3,849
	Cogeneration	5,024	4,934	5,024	5,024	5,024	5,024	5,484
	Combined Cycle	1,746	1,746	1,746	1,746	1,746	1,746	1,746
	Simple Cycle	1,059	916	916	1,059	964	916	916
	Coal-to-Gas	1,581	1,581	1,581	0	1,581	1,581	1,581
	Hydro	894	894	894	894	894	894	894
	Wind	3,045	2,945	3,045	3,045	3,045	3,045	3,045
	Solar	200	200	200	200	200	200	200
	Other	479	479	479	479	479	479	479
	Total	17,877	17,544	17,734	17,877	17,782	17,734	18,194

Therefore, it is very clear that forecasting is the most important element power system operation to ensure the utility could fulfill the demand of consumers and could be generated delivered efficiently.

V. Summary

Power system operation in Alberta is managed by AESO which is responsible to coordinate operation of the power grid and makes sure that the supply of power is in constant balance with the demand for power across the province. AESO also conduct the supply and demand forecasting in order to have a clear direction for planning the provincial power generation and transmission system and operating wholesale and retail electricity market. The improvement of power system management and operation in Alberta is significantly affected by the transformation from regulated to deregulated structure.

VI. Acknowledgement

This project is supported by The Ministry of Research, Technology, and Higher Education **(MORTHE)** Indonesia in cooperation with **SAIT** MacPhail School of Energy, Alberta, Canada.

This project is supervised by **Shashi Persaud, PhD, P.Eng, G.Dip.Ed** , Electric Machines & Power Systems Instructor in SAIT.

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