BUSINESS SOLUTION FOR DEMAND RESPONSE IN THAILAND GRID MODERNIZATION DEVELOPMENT

PARINYA SONSAARD

A Thesis Submitted to the Graduate School of Naresuan University
in Partial Fulfillment of the Requirements
for the Doctor of Philosophy in (Smart Grid Technology)
2021

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has been approved by the Graduate School as partial fulfillment of the requirements for the Doctor of Philosophy in Smart Grid Technology of Naresuan University

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ABSTRACT

This research focused on the business solution for DR in Thailand for Thailand's utilities and policymakers. The key success factor in the DR business is DRR collection by a LA. This research proposes the future energy market, the future DR business, LA organization, the new role of future DR energy market in the future energy market composed of SO, TSO, DRCC, DSO, LA#1, LA#2, and DRR, the DR market size expectation, the SWOT analysis, the business model canvas, and the LA#1 financial analysis for the development of LA#1 business solution in Thailand's energy market.

Thailand's DR market size expectation is 1.4 GW - 2.5 GW by 2021-2037 which DR can replace the peaking power plant. The SWOT analysis shows the strengths, opportunities, weaknesses, and threats of Thailand's utilities on DR business. The business model canvas shows activities related to LA#1 on the LA business operated by Thailand's utilities. LA#1 obtains benefits from the commission of CP and EP paid by DRCC. DLC and EDRP are DR programs managed by LA#1. LA#1 obtains income from 30 percent of incentive paid to DRR by DRCC and consulting fee for a DRR. LA#1 invests in infrastructure costs and pays monthly operation costs. NPV and IRR of LA#1 are 175.43 M฿ and 10 percent, respectively shown in the financial analysis. LA#1 can get more benefits by deducting the investment and operation cost and by obtaining more benefits by the service the

LAMS to a private company.

Finally, Thailand utilities have to modernize their electrical system using smart grid technology. DR is one of the key technologies that reduce electricity usage in the high-demand period reduced investment costs in the generation, transmission, and distribution system. Furthermore, LA business is a new business of Thailand's energy market which LA can manage DRR of the DR market. Accordingly, DR are an important role in the electrical system provided by Thailand's utilities so that their electrical network will be modernized by using smart grid technology.

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PARINYA SONSAARD

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CHAPTER 1 INTRODUCTION

1.1 Statement of the problem

Thailand's utilities plan to improve the existing electrical grid to be more efficient in order to support the government's policy of country's development and various applications in the long run due to changes in society, economy, and technology.

New technologies, such as Blockchain, Electric Vehicle (EV), Distributed Generation (DG), and Virtual Power Plant (VPP) is a technology that will generate electricity and trade between customers (Peer to Peer). Utilities must be prepared an energy market or Energy Trading Platform to trade between DG and customers.

Based on the driving forces, the future of the electricity trading market will change. Therefore, Thailand's utilities also have to adjust to survive such changes as well.

Utilities' planning for the improvement of the generation, transmission, and distribution system to modernize support the future electrical system technology. The utility will apply smart grid technology to manage various electrical systems more efficient and also using the most effective assets. The formulation of a conceptual framework for improving the transmission and distribution system to be modern, supporting future electrical system technology, the utility has to apply various technologies that will be used in the generation system, transmission system, distribution system, and cyber security. A modern business model including the behaviour of electricity users for an investment that is worthy of electricity which will allow the electricity to be able to support the changes in the electricity market.

Demand Response (DR) is one of the key technologies of the energy market in the future. DR reduce customer's electricity usage during high demand period in order to reduce the demand for electricity in the country. DR will save the investment cost in generation system, transmission system, and distribution system.

1.2 Purpose of this study

1. To analyze electricity market for Thailand demand response.
2. To design business solution for demand response in Thailand grid modernization development.

1.3 Limitations of the study

This research developed the business solution for Thailand demand response of Thailand's utilities. The research develops future electricity market, role of future Thailand's energy sector, Thailand's DR business, Thailand's LA business, Thailand's LA organization, Thailand DR market size expectation, Thailand's business model, and Thailand's preliminary financial analysis of LA#1.

1.4 Scope of this study

The business solution for Thailand demand response is scope to:

1. The possible market of demand response for Thailand.
2. The business solution for demand response in Thailand grid modernization development.

3. The business solution for demand response focus on Provincial Electricity Authority.

1.5 Keywords

Smart Grid, Grid Modernization, Demand Response, Load Aggregator

1.6 Benefits of the study

The research on the business solution for demand response in Thailand grid modernization development will get the benefit as follows:

1. The possible market of demand response for Thailand.
2. The business solution for demand response in Thailand grid modernization development.

CHAPTER 2 LITERATURE REVIEW

New technology of electrical system components, for example, renewable energy (RE), energy storage system (ESS), electric vehicle (EV), automated demand response (ADR), IoT device etc. challenge utilities to transform from traditional grid to be modern grid or grid modernization [1] as shown in Figure 1.

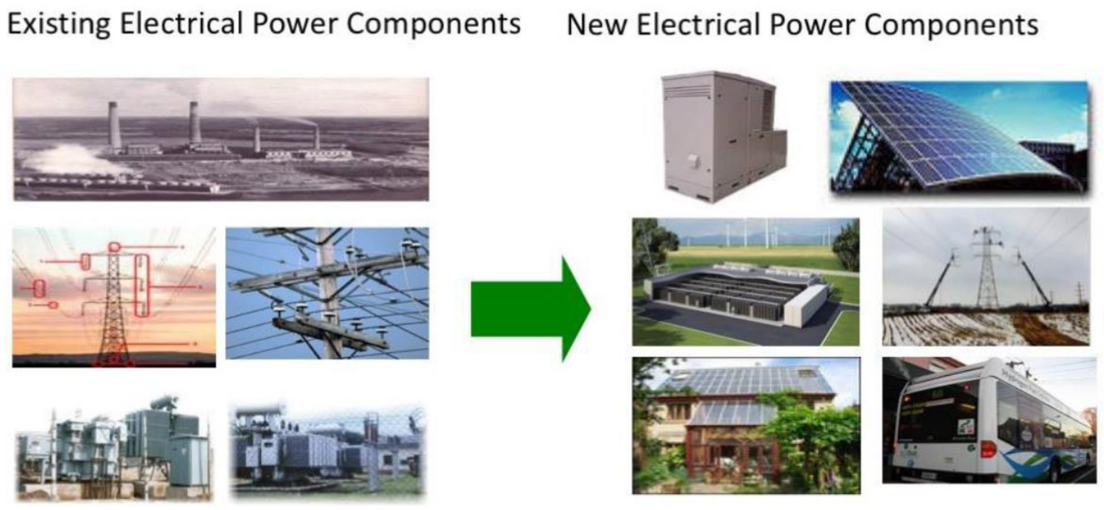

Figure 1 Transition from existing to new electrical system components [1]

2.1 Smart Grid

2.1.1 Smart Grid Definition

Title XIII-Smart Grid of the Energy Independence and Security Act of 2007 United State of America provides the description of Smart Grid [2] as: "It is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve each of the following, which together characterize a Smart Grid:

(1) Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.

(2) Dynamic optimization of grid operations and resources, with full cyber-security.

(3) Deployment and integration of distributed resources and generation, including renewable resources.

(4) Development and incorporation of demand response, demand-side resources, and energy-efficiency resources.

(5) Deployment of 'smart' technologies (real-time, automated, interactive technologies that optimize the physical operation of appliances and

consumer devices) for metering, communications concerning grid operations and status, and distribution automation.

(6) Integration of 'smart' appliances and consumer devices.

(7) Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal storage air conditioning.

(8) Provision to consumers of timely information and control options.

(9) Development of standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid.

(10) Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services."

The European Union Commission Task Force for Smart Grids provides smart grid definition [3] as: "A Smart Grid is an electricity network that can cost efficiently integrate the behavior and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety. A smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies in order to:

(1) Better facilitate the connection and operation of generators of all sizes and technologies.

(2) Allow consumers to play a part in optimizing the operation of the system.

(3) Provide consumers with greater information and options for how they use their supply.

(4) Significantly reduce the environmental impact of the whole electricity supply system.

(5) Maintain or even improve the existing high levels of system reliability, quality, and security of supply.

(6) Maintain and improve the existing services efficiently."

Thailand Smart Grid Development Master Plan for 2015-2036 provides Smart Grid definition [4] as: “The development of electrical systems which can respond to work more intelligently or with greater ability by using fewer resources with efficiency, reliability, safe, sustainability, and environmentally friendly. Smart Grid can be achieved by applying information and communication technology systems, sensor systems, database systems, and automatic control technology which make power systems can recognize more information in the system for automatic decision-making. Smart Grid must occur throughout the electrical system covering the generation system, distribution system, and user's electrical system.”

2.1.2 Smart Grid Technology

According to Thailand Smart Grid Development Master Plan for 2015-2036, Smart Grid elements include [4]:

(1) Information and Communication Technology (ICT)

(2) Power generation and transmission system

(3) Supervisory Control and Data Acquisition (SCADA)

(4) Advanced Metering Infrastructure (AMI) and Demand Response (DR)

(5) Energy Management System (EMS), Home Energy Management System (HEMS), Building Energy Management System (BEMS), Factory Energy Management System (FEMS), and Community Energy Management System (CEMS)

2.2 Grid Modernization

2.2.1 Grid Modernization Definition

The Grid Modernization Multi-Year Program Plan, U.S. Department of Energy defined Grid Modernization [5]: "Transitioning to a modernized grid is a process, not an end-point. It is a transformation from a monolithic grid to one that is modular and agile: from centralized generation characterized by decisions driven by affordability and reliability, to one of both centralized and distributed generation and intelligent load control characterized by decisions driven by cost and environmental sustainability, contained events, personalized energy options, and security from all threats."

The 50 States of Grid Modernization: Q4 2018 Quarterly Report & 2018 Annual Review Executive Summary [6] defined that "Grid Modernization is a broad term, lacking a universally accepted definition. In this report, the authors use the term grid modernization broadly to refer to actions making the electricity system more resilient, responsive, and interactive. Specifically, in this report grid modernization includes legislative and regulatory actions addressing:

(1) Smart grid and advanced metering infrastructure
(2) Utility business model reform
(3) Regulatory reform
(4) Utility rate reform
(5) Energy storage
(6) Microgrids
(7) Demand response."

Thailand Grid Modernization is Improvement and development of generation system, transmission system, and distribution system by using modern technology that includes improving the policy and rules accordingly to be used to change the electrical system to be able to manage, control, and operate stably, reliably, efficient, flexible, and environmentally friendly [7].

2.2.2 Grid Modernization Initiative[8]

The Grid Modernization Multi-Year Program Plan, U.S. Department of Energy said Grid Modernization Initiative consist of six attributes and six technical areas [5]:

Grid Modernization attributes

(1) Resilient Quick recovery from any situation or power outage
Reliability Improves power quality and fewer power outages
(3) Secure Increases protection to our critical infrastructure
(4) Affordable Maintains reasonable costs to consumers
(5) Flexible Responds to the variability and uncertainty of conditions at one or more timescales, including a range of energy futures
(6) Sustainable Facilitates broader deployment of clean generation and efficient end use technologies

Grid Modernization Technical Areas

(1) Devices and Integrated Systems Testing
(2) Sensing and Measurements
(3) System Operations, Power Flow, and Control
(4) Design and Planning Tools
(5) Security and Resilience
(6) Institutional Support

Grid Modernization Issues with a Focus on Consumers, Critical Consumer Issue Forum (CCIF) focus on five topic areas [9]:

(1) Consideration of Costs, Benefits and Risks
(2) Consumer Protections
(3) Privacy and Security
(4) Consumer Education and Communication
(5) Federal/State Relation

2.3 Advanced Metering Infrastructure (AMI)

2.3.1 AMI Definition

Federal Energy Regulatory Commission defined Advanced Metering is: "A metering system that records customer consumption [and possibly other parameters] hourly or more frequently and that provides for daily or more frequent transmittal of measurements over a communication network to a central collection point" [10].

2.3.2 AMI Technology

Smart meter is a key device on Smart Grid which it have the key function as follows [3]:

(1) Remote reading of metrological register and provision of these values to designated market organization(s)
(2) Two-way communication between the metering system and designated market organization(s)
(3) Meter supporting advanced tariffing and payment systems
(4) Meter allowing remote disablement and enablement of supply
(5) Communicating with individual devices in the home or building
(6) Meter providing information via portal/gateway to an in-home/building display or to auxiliary equipment

Figure 2 shows Advanced Metering Infrastructure (AMI) the key components of PEA Smart Grid at Pattaya City. AMI have component as follows:

(1) Smart Meter: It have the metering part and communication part
(2) Communication system: AMI can use various communication depend on geography, type of city or resident, and local regulation
(3) Head-end system (HES): This device use for managing group of meters and send data to MDMS
(4) Meter Database Management System (MDMS): It use for managing and collect data.
(5) Enterprise Service Bus (ESB): It use for exchange information among applications and MDMS

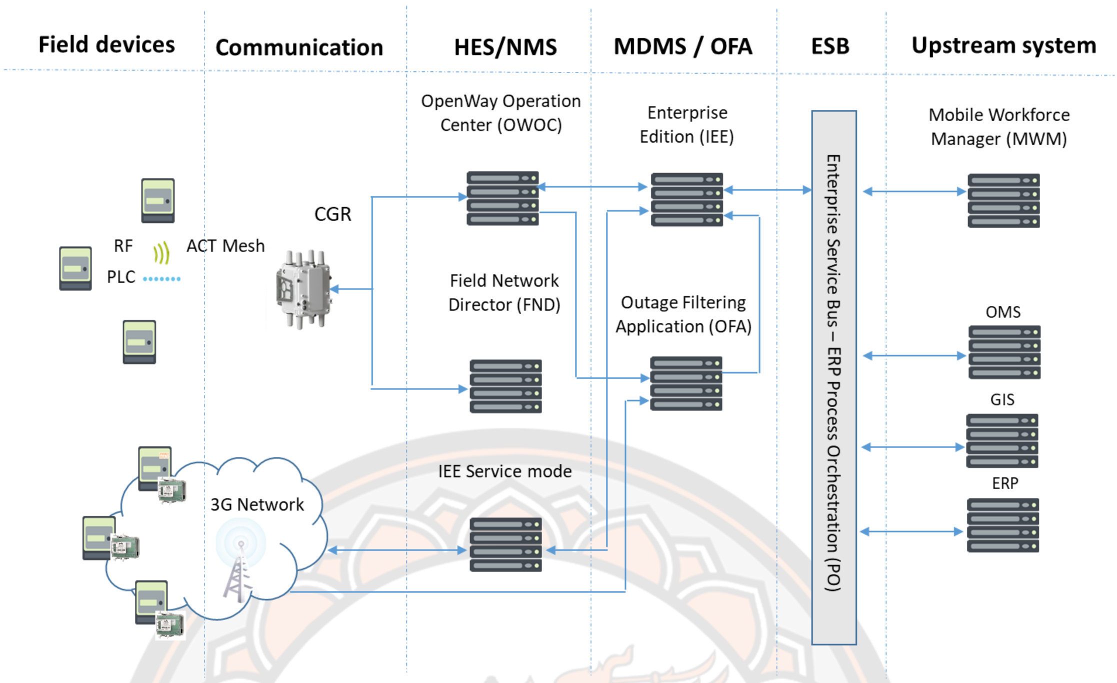

Figure 2 Advanced Metering Infrastructure components

2.4 Electric Vehicle (EV)

2.4.1 EV Definition

Electric Vehicle is a vehicle which is propelled fully (Battery Electric Vehicle: BEV) or partially (Hybrid Electric Vehicle/Plug-in Hybridge Electric Vehicle: HEV/PHEV) by an electric motor instead of an internal combustion engine.

2.4.2 EV Management Technology

EV is electrical load when it plug-in to electrical grid at a charging station or dwelling. EV home charger typically is an on-board charger which is a single-phase charger. It may affect with a utility's distribution grid. The utility has to reduce an effect by control an EV home charger [8].

2.5 Demand Response

2.5.1 Demand response definition

Demand response (DR) is a dynamic change of electrical demand from normal patterns in specific period that responds to price or incentive of a utility signal to suggest a participated customer or a demand response resource (DRR) to reduce electrical demand during a period of peak demand to secure the electrical system [10].

2.5.2 Role of DR in electrical system planning

DR which is a key function of electrical system in the near future can change the electrical demand in specific period instead of using a peaking power plant. DR can be grouped into two categories as shown in Figure 3 [11]:

1) Price-Based DR

Price-based DR or economic DR one of the DR options can manage demand by price signals as follows:

a. Time of Use rates (TOU)
b. Day-ahead hourly pricing (Day-ahead or near-real-time: RTP)
c. Real-time hourly pricing (RTP)/ Critical peak price (APP)

2) Incentive-based DR

Incentive-based DR or reliability DR is another of DR options can manage demand by incentive to a DRR as follows:

a. Capacity/ancillary services programs
b. Demand bidding/buyback
c. Emergency programs
d. Interruptible programs

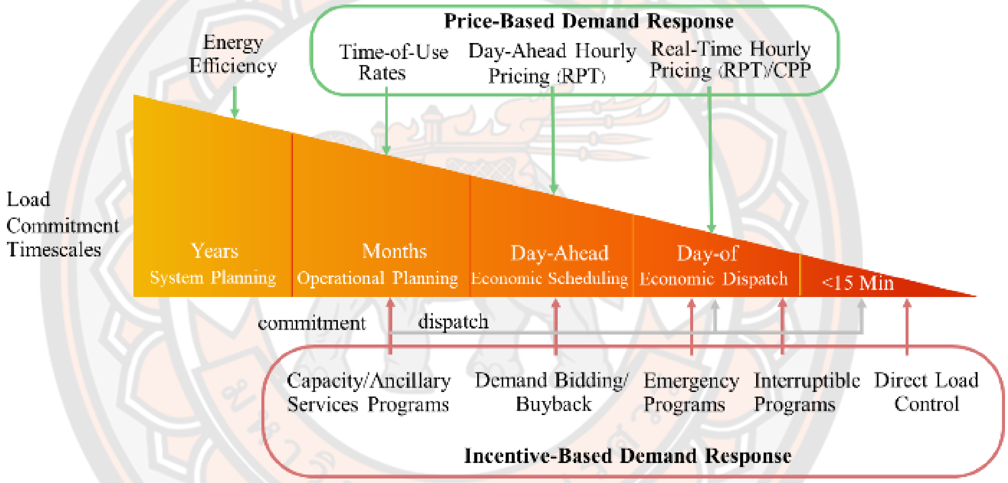

Figure 3 Role of DR in electrical system planning and operation [11]

2.5.3 OpenADR standard

OpenADR, the standard for implementation of DR, is open and interoperable for command and information exchange among DR market [12]. Figure 4 shows an OpenADR standard architecture contains components as follows [12]:

1) Virtual Top Node

Virtual Top Node (VTN) is a DR server that can send OpenADR command to VEN and receive metering data from VEN. This function is for a demand response control center (DRCC).

2) Virtual End Node

Virtual End Node (VEN) is a client device which respond to VTN command such as an energy management system (Building Energy Management System: BEMS, Home Energy Management System: HEMS, Factory Energy Management System: FEMS), direct load control: DLC, a thermostat. This function is for a DRR.

3) Virtual End Node/ Virtual Top Node

VEN can be a server which can get a command from VTN and send command to VEN as VTN. This function is for an LA which is called load aggregator management system (LAMS).

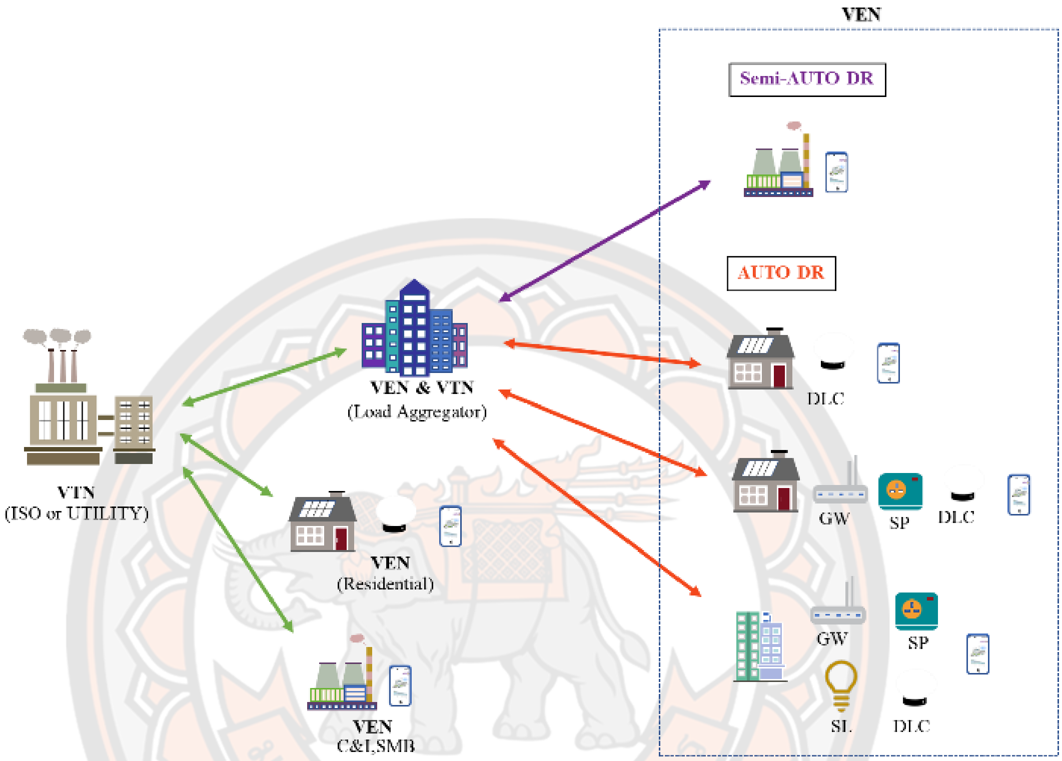

Figure 4 OpenADR 2.0 b standard [13]

2.5.4 Level of DR automation

Levels of DR automation can be defined as follows [14]:

1) Manual DR

A utility or a LA send an email or a short message to a DRR, then a DRR manually switches off apparatus.

2) Semi-Automated DR

A utility or a LA send a command to a DRR, then a DRR acknowledges an energy management system which was programmed to reduce to use energy.

3) Fully Automated DR or Automated DR

A utility or a LA send a command to a DRR, then a DRR's energy management system reduces energy usage automatically as a DRR was programmed.

2.5.5 Thailand DR architecture

The current Thailand's electrical energy market is an enhanced single buyer (ESB) which means only Electricity Generating Authority of Thailand (EGAT) who can purchase electric energy from any power producer in Thailand and import from other countries. Thailand's electricity retailers can purchase eletricity only from EGAT as shown in Figure 5. A very small power producer (VSPP) may can sell electric energy to retailer depending upon policy.

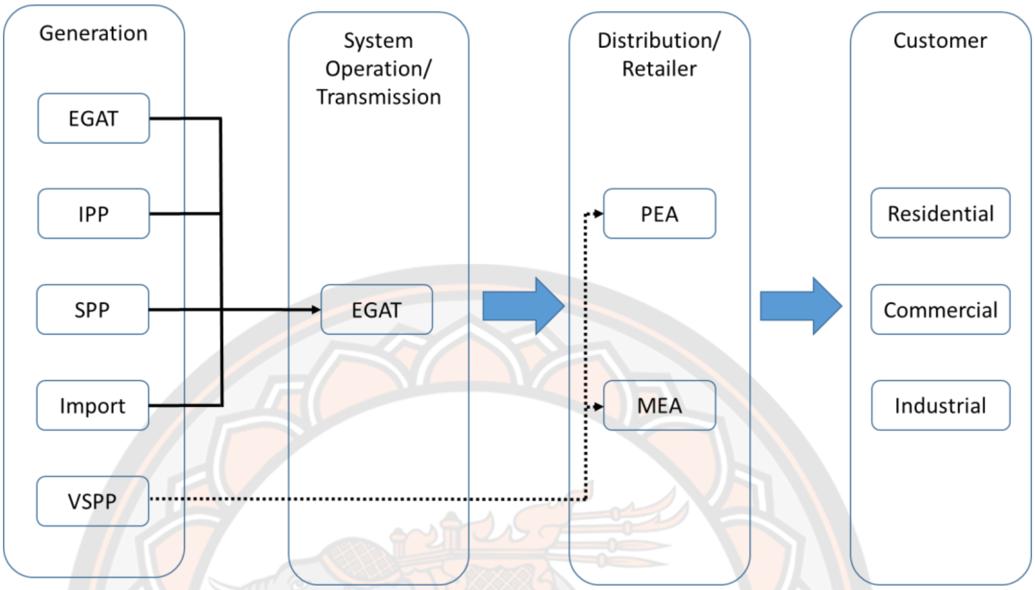

Figure 5 Current Thailand' electricity energy market

Figure 6 shows Thailand's DR architecture will use for DR market in Thailand [15]. EGAT acts as Demand Response Management System (DRMS). Provincial Electricity Authority (PEA) and Metropolitan Electricity Authority (MEA) acts as a Load Aggregator Management System (LAMS). In the near future, the private sector will act as LAMS level 2.

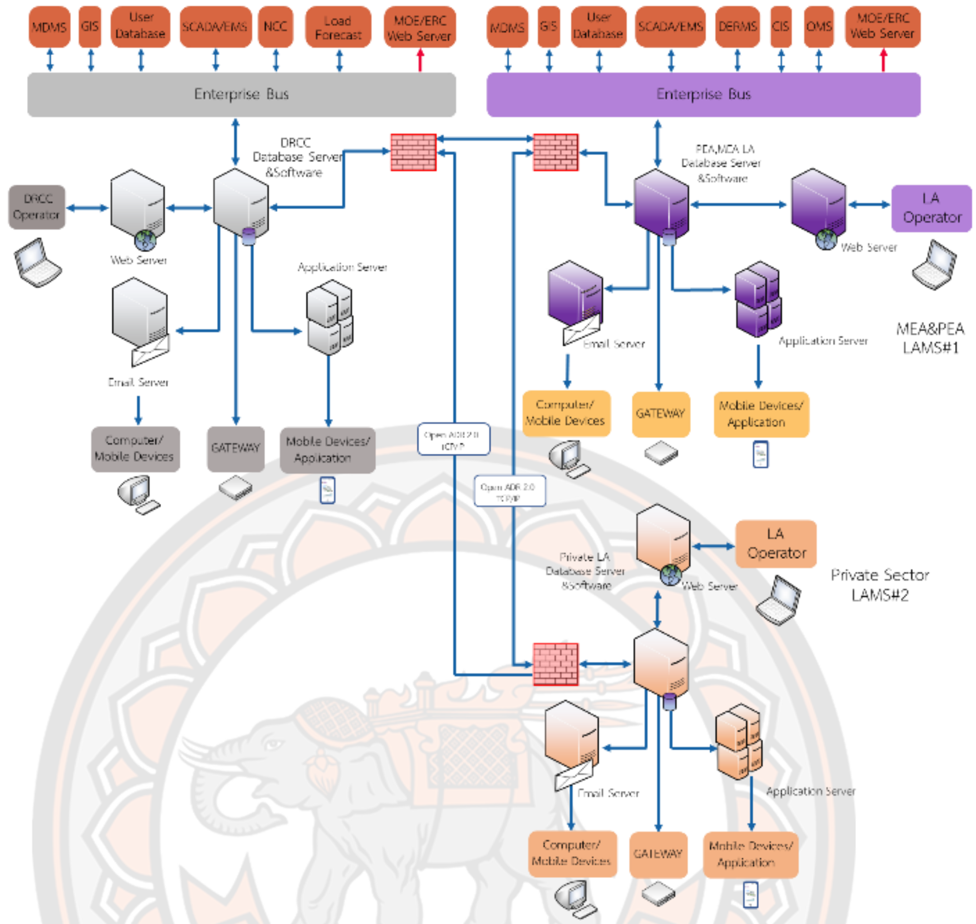

Figure 6 Thailand's Demand Response Architecture

2.5.6 Thailand's ADR implementation

Thailand's utility plans to implement ADR using OpenADR protocol as shown in Figure 7 EGAT acts as demand response control center or demand response management system or virtual top node (DRCC/DRMS/VTN) who maintains electrical system stability and calls DR. DRCC sends command to a LAMS to reduce peak demand of DRR. PEA/MEA acts as load aggregator level 1 (LA#1/VEN/VTN). LA#1 gets command from DRCC before LA#1 calculates and selects target customer to reduce peak demand. A DRR acts as VEN which is willing to join DR program. Private sector acts as load aggregator level 2 (LA#2). Green line is communication for command signal and metering data which is two-way communication from DRCC to LA#1, then from LA#1 to LA#2 or customers [12]. LAMS shall use utility's smart meters to measure and verify the reduction of electricity demand and energy. An additional real-time meter may be required to measure a real-time load reduction of a DRR.

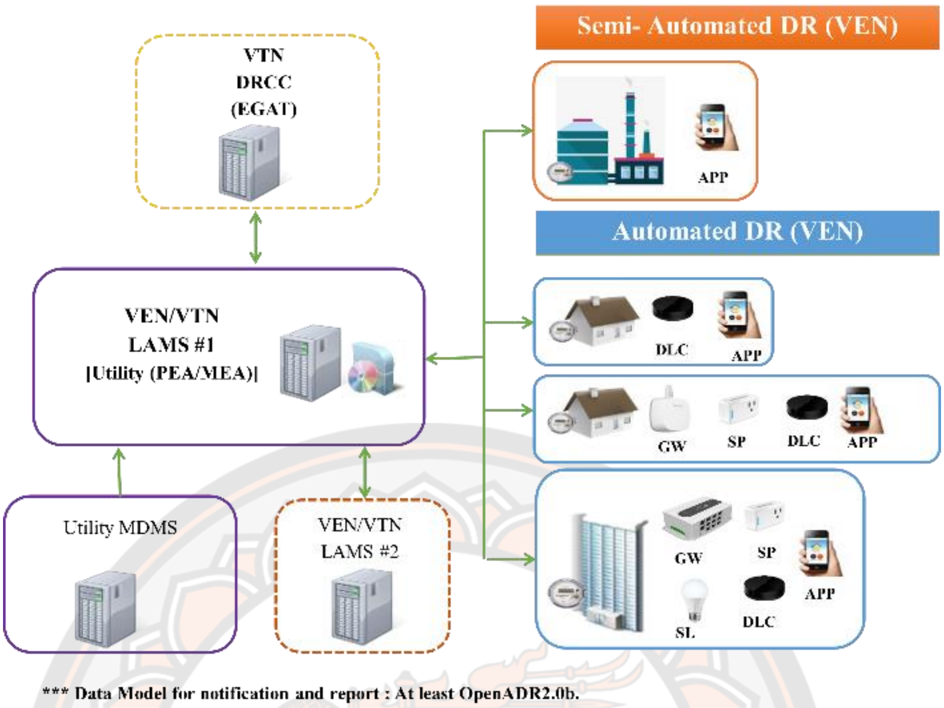

Figure 7 PEA's Pilot DR Implementation Plan

2.5.7 Thailand DR draft program and tariff

Thailand Energy Regulation Commission had a public hearing on draft of Thailand's DR program and tariff on September 8th, 2016. The DR program and tariff are shown in Table.1, Table.2, and Table.3 [16].

Table 1 Draft of Thailand's DR Program and Tariff [16]

Detail	DR Program			
	Critical Peak Pricing (CPP)	Interruptible Load Program (ILP)	Direct Load Control (DLC)	Emergency DR Program (EDRP)
Objective	- Yearly Peak Cut	- Emergency - Yearly Peak Cut	- Emergency - Yearly Peak Cut	- Gas Supply - Yearly Peak Cut
Goal	100 MW	200 MW	50 MW	150 MW
Target Group	Customer Category 3, 4, 5	Customer Category 3, 4, 5 Group 1 IL ≥ 1 MW Group 2 1 MW ≥ IL ≥ 500 kW	1.Residential and Small Commercial Customer > 12 kV 2. Customer Category 3, 4, 5	Customer Category 3, 4, 5
Participation	Enroll with Utility	Enroll with Utility	Enroll with LA	Enroll with LA
Period	April-May	9.00 A.M. -10.00	Summer and	Gas Supply

Detail	DR Program			
	Critical Peak Pricing (CPP)	Interruptible Load Program (ILP)	Direct Load Control (DLC)	Emergency DR Program (EDRP)
		P.M.	Emergency	
Dispatching	April-May	1 Hour Ahead	15 Minute Ahead	24 Hour Ahead
Baseline	-	Meter Reading Before Calling	Meter Reading Before Calling	10 Day Before, Working Day and Weekend
Tariff/ Incentive	As shown in Table.2	As shown in Table.3	Incentive (Baht/kW/Month) #1 42 $\leq$ 3 Hr./Time, 2 Time/Day, 10 Time/Month, 40 Time/Year #2 21.42 $\leq$ 3 Hr./Time, 1 Time/Day, 10 Time/Month, 20 Time/Year #3 42.84 $\leq$ 6 Hr./Time, 1 Time/Day, 10 Time/Month, 20 Time/Year	Incentive 5.63 Baht/kWh
Penalty	High Rate at CPP Period	Current Interruptible Rate	Current Interruptible Rate	54.14 Baht/kW

Table 2 Tariff of Critical Peak Pricing (CPP) [16]

Voltage (kV)	Critical Peak (Baht/kWh)	Peak (Baht/kWh)	Off-Peak (Baht/kWh)
>69	9.1617	4.1283	1.3379
12-24	9.3424	4.2097	1.3475
<22	9.6659	4.3555	1.3646

Table 3 Tariff of Interruptible Load Program (ILP) [16]

Voltage (kV)	#1 (Baht/kW/Month)	#2 (Baht/kW/Month)	#3 (Baht/kW/Month)
>69	31.3	52.72	31.3
12-24	56.12	94.53	56.12
	≤ 3 Hr./Time, 2 Time/Day, 10 Time/Month, 40 Time/Year	≤ 3 Hr./Time, 1 Time/Day, 10 Time/Month, 20 Time/Year	≤ 6 Hr./Time, 1 Time/Day, 10 Time/Month, 20 Time/Year

2.5.8 Thailand DR business study by Energy Policy and Planning Office

Report of Energy Policy and Planning Office (EPPO) shows that the DR capacity from 18 percent of spinning reserve capacity is 200 MW and from non-spinning reserve is 500 MW [17]. The DR from spinning reserve and non-spinning reserve is 700 MW and the maximum DR capacity is 1,250 MW referring to Thailand Power Development Plan 2015-2036 (PDP2015) [16]. DR incentive of Traditional Utility model (TU model), Load Aggregator model (LA model), and Customer-provisioned model (CP model) are shown in Table 4.

Table 4 DR incentive of TU model, LA model, and CP model [17]

	Result	TU Model	LA Model	CP model
SO/DRO	NPV (M฿)	112.66	1,739.08	4,892.77
	FMIRR (%)	7.41%	17.03%	19.52%
	EMIRR (%)	34.27%	51.90%	53.99%
	Payback (Month)	1	1	1
LA	NPV (M฿)	-	166.10	-
	FIRR (%)	-	16.87%	-
	Payback (Month)	-	5	-
Platform	NPV (M฿)	-	-	260.57
	FIRR (%)	-	-	8.25%
	Payback (Month)	-	-	10

	Result	TU Model	LA Model	CP model
DR supply	NPV (M฿)	1,026.0	-	15,357.13
	FIRR (%)	108.57%	-	68.02%
	Payback (Month)	11	-	18
Possibility DR tariff	AP (Baht/kW/month)	102.36	27.32	36.40
	EP (Baht/kWh)	6.00	6.00	6.00

2.5.9 DR implementation in other country

DR have implemented in many countries such as United State of America, Europe country, South Korea, etc.

United State of America test Fully-automated DR (Auto-DR) and define three levels of DR automation that compose of Manual DR, Semi-automated DR, and Fully-automated DR (Auto-DR) [14]. U.S. Department of Energy report benefit of DR in electricity markets and recommendations for achieving that U.S. Department of Energy define role of DR in electric power systems, show benefits of DR, and recommend for achieving the benefits of DR [11]. In 2019, U.S.A. DR market size at 31,020 MW and actual peak DR saving at 11,334 MW [18].

Many countries in European Commission (EU) open DR market in various program that EU have the status of member states regulation three group. The first group seriously engage with DR reforms, the second group are in process of enabling DR through the retailer only, the third group enables both DR and independent aggregation [19]. In 2015, DR market size in EU at 52.35 GW [20].

South Korea develop a demand-side management solution (DSMS) for demand response (DR) aggregator. The DSMS real-time calculates the customer baseline (CBL), relative root means squared error (RRMSE), and the settlement [21]. Korea Power Exchange (KPX), who is to control of the operation of Korea’s electric market, report DR market size around 4,000 MW [22].

2.6 Peaking Power Plant

The peaking power plant is a power plant that generates power on-peak period to support fluctuation of power system using gas or hydropower [23], [24].

Summary of Literature Review

Grid Modernization is the process of improving the electrical system, business model, regulation, code, and law to support new technology such as a distributed energy, energy storage, electric vehicle, etc. Grid Modernization can improve reliability, energy security, efficiency, cybersecurity, sustainable, dynamic optimization, and environmental friendliness.

From literature review shows that Grid Modernization for DR business have three layers as shown in Figure 8 as follow:

1. Regulatory layer

Regulatory layer composes of DR business policy, LA business policy, Grid code, and Service code.

2. Business layer

Business layer composes of ISO/TSO/DSO/DRCC, Retailer, LA, and DRR.

3. Technical layer

Technical layer composes of Smart Grid, data analytics, DRMS, LAMS, AMI, DLC, HEMS/BEMS/FEMS, and EV home charger management system.

Grid Modernization for DR business is the process for implementation DR business solution for demand response in Thailand grid modernization development that include regulatory layer, business layer, and technical layer.

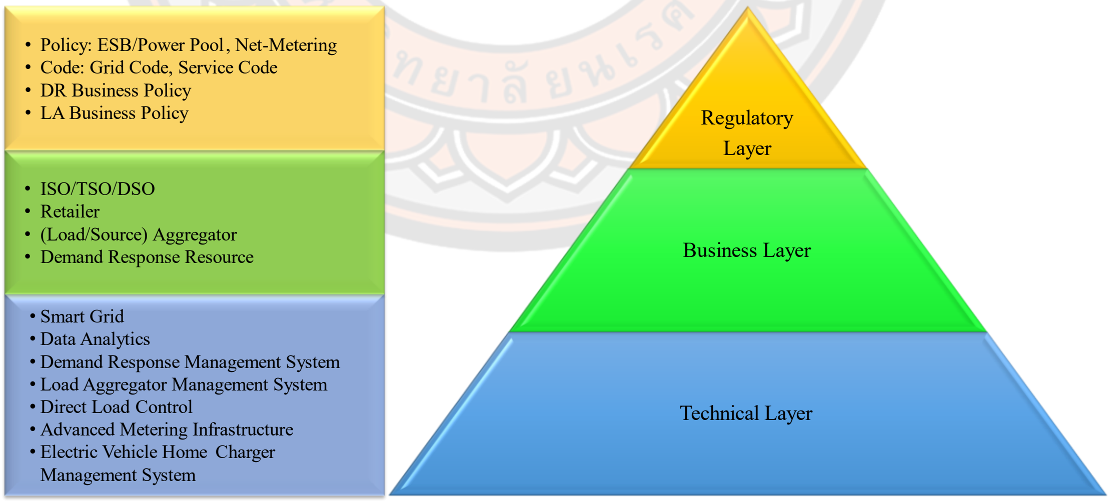

Figure 8 Grid Modernization for DR business

CHAPTER 3 METHODOLOGY

3.1 Research Methodology

The study and development of business solution for demand response in Thailand grid modernization development. This research aims to propose the future energy market, the future DR business, LA organization, the new role of future DR energy market in the future energy market composed of SO, TSO, DRCC, DSO, LA#1, LA#2, and DRR, the DR market size expectation, the SWOT analysis, the business model canvas, and the LA#1 financial analysis for the development of LA#1 business solution in Thailand's energy market. The complete research methodology is explained in three steps as follows.

1. Analyze electricity market for Thailand demand response
2. Design business solution for demand response in Thailand grid modernization development
3. Analyze and summarize business solution for demand response in Thailand grid modernization development

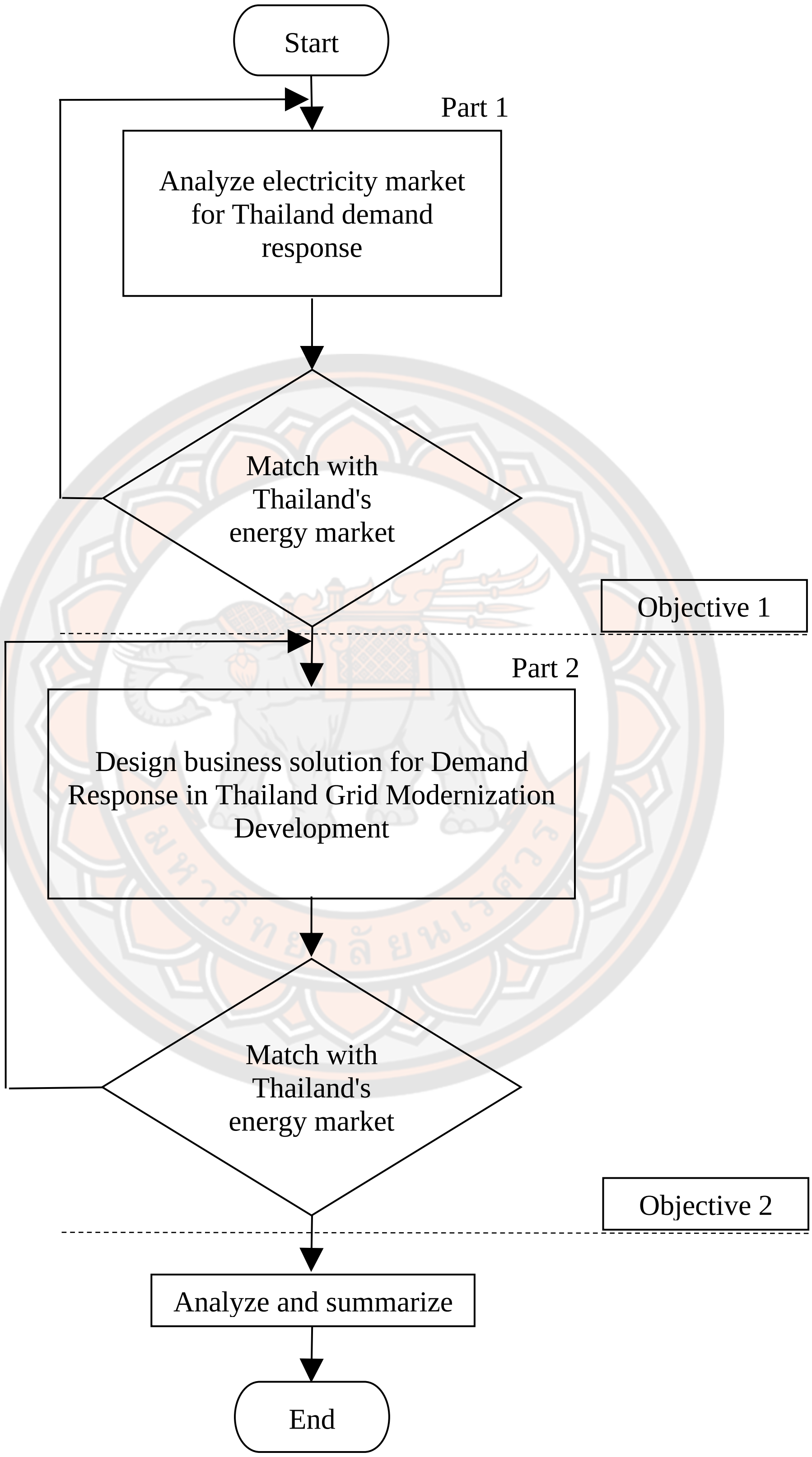

Figure 9 Flowchart of dissertation methodology

3.2 Research step

Figure 9 shows flowchart of dissertation methodology, which consists of three steps, all steps will be described as bellow.

3.2.1 STEP 1: Analyze electricity market for Thailand demand response

This part of the research focuses on design the future energy market, DR business, role of Thailand's future energy market, LA business model, and LA organization that matches Thailand's energy market.

3.2.2 STEP 2: Design business solution for demand response in Thailand grid modernization development

This part of the research focuses on Thailand's DR market size expectation, Thailand's DR business model that focuses on SWOT analysis and business canvas, and financial analysis.

3.2.3 STEP 3: Analyze and summarize

After all the research steps are done, all results will be analyzed and summarized to follow the objectives of this research. The result will be summarized and it also will give more detail about the future research area according to the development of DR and LA business.

CHAPTER 4 RESULT ANALYSIS AND DISCUSSION

This section describes the research results, which follow the methodology in Chapter 3. The results and discussion follow two steps: the first, Analyze electricity market for Thailand demand response, then Design business solution for demand response in Thailand grid modernization development. All the results and discussion details described as presented below.

4.1 Thailand ADR implementation framework of Thailand utility

4.1.1 Thailand's proposed DR infrastructure

OpenADR protocol as shown in Figure 10 are used by Thailand's utilities that support semi-automated DR and automated DR (ADR) [14]. Virtual top node (VTN)/ demand response control center (DRCC)/ or demand response management system (DRMS) maintains electrical system stability and calls DR responsible by EGAT. VTN/ DRCC/DRMS DR command is sent to a LA#1 to reduce peak demand of a DRR or LA#2 by VTN/ DRCC/DRMS. Load aggregator level 1 (LA#1/VEN/VTN) is responsible by PEA/MEA. LA#1 gets command from DRCC before LA#1 calculates and selects target customer or LA#2 to reduce peak demand. A DRR is VEN which joins DR program. Load aggregator level 2 (LA#2) is responsible by Private sector that collects a group of a DRR. The red line is communication for command signal and metering information which is two-way communication from DRCC to LA#1, then from LA#1 to a DRR or LA#2 [12], [13], [14], [15]. LAMS uses utility's smart meters to measure and verify the reduction of electricity demand and energy. Real-time monitoring may be required to measure load reduction of a DRR.

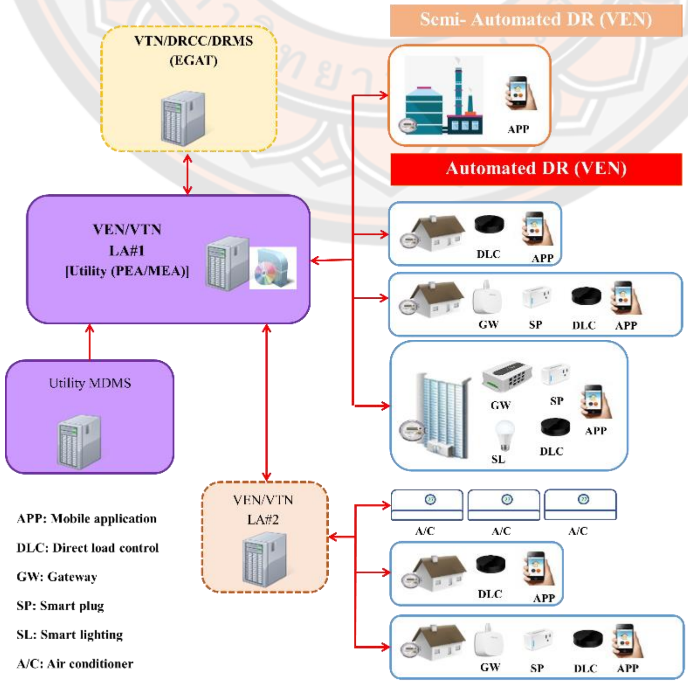

Figure 10 Thailand's utilities pilot DR implementation plan [13]

4.1.2 Thailand's DR business market

In this part, the development of DR energy market and LA business of Thailand's utilities is proposed. It will change from ESB into a new era of energy market as other countries that will change role of current utility described in Figure 10 and Figure 11. The detail of energy market change in Thailand consists of:

4.1.2.1 Thailand's future energy market

Thailand future electricity market has to change a role of the utilities as shown in Figure 11 and Figure 12. Figure 11 shows Thailand future electricity market at the beginning stage. Figure 12 shows Thailand future electricity market at the mature stage [25].

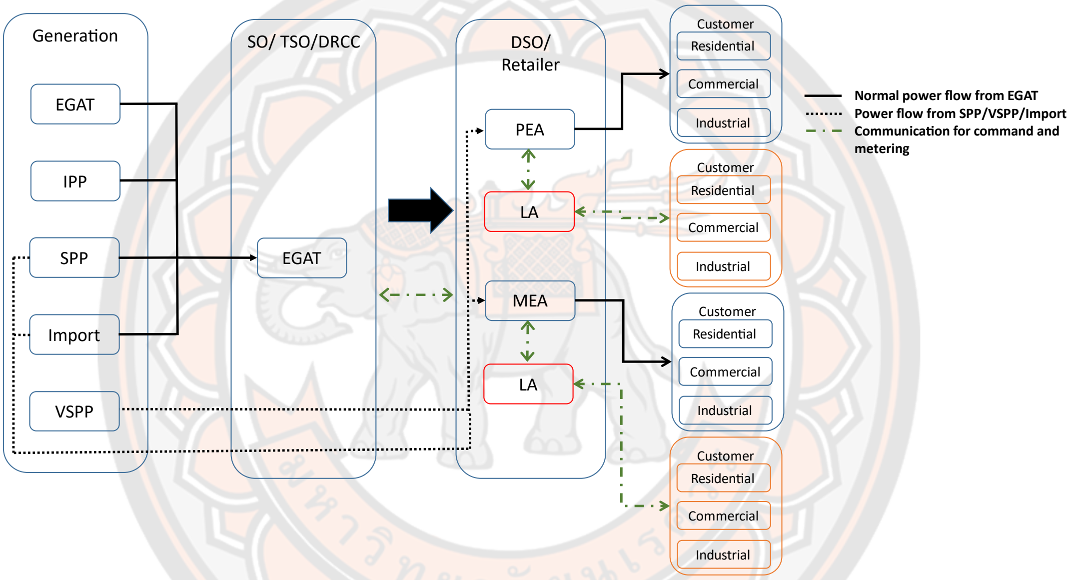

Figure 11 Thailand's future electricity market at the beginning stage

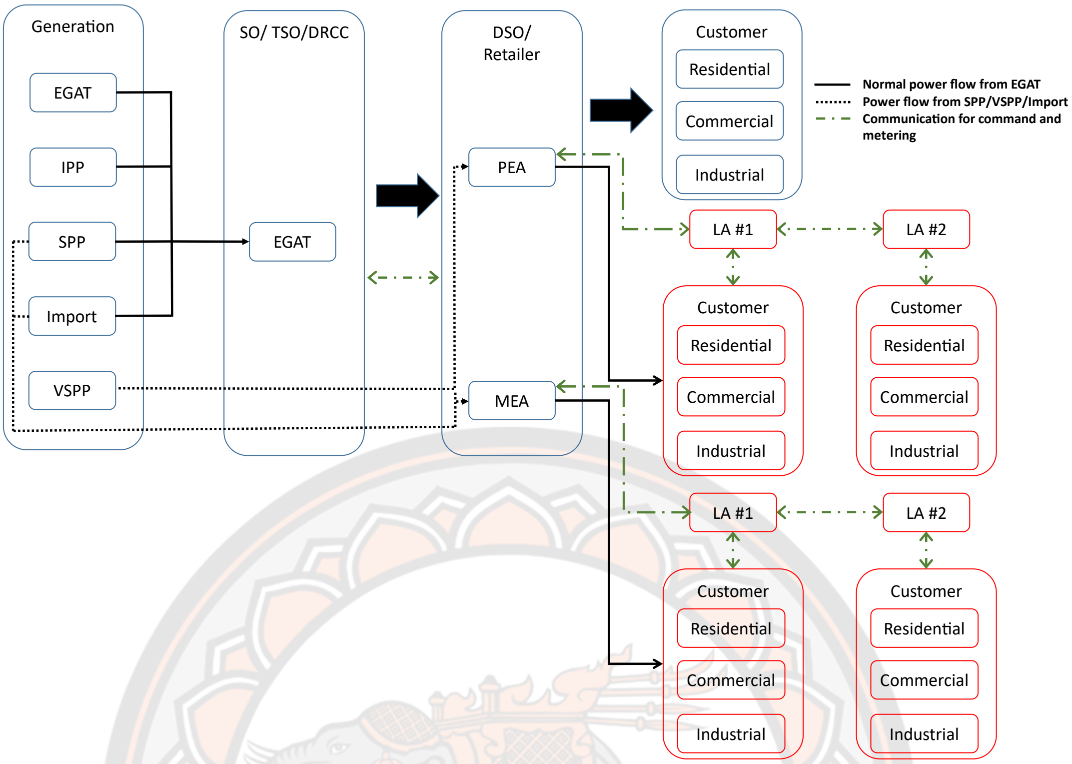

Figure 12 Thailand's future electricity market at the mature stage

Thailand energy market will have system operator (SO: EGAT), transmission system operator (TSO: EGAT), demand response control center (DRCC: EGAT), distribution system operator (DSO: PEA/MEA), Retailers (PEA/MEA/Private sector), and load aggregator (LA). LA will be a new player in the energy market. PEA/MEA/EGAT and a private sector can be LA.

1) At the beginning stage

At the beginning stage, generation utility (EGAT) will establish the DRCC to manage and control LA for the DR program. A distribution and retailer utility (PEA/MEA) will establish the LA business unit to support the DR program. LA is not responsible for a retailer as a utility. LA is a newcomer of the electrical energy market to aggregate and manages a group of DRRs. DR and LA business may be small market and gain low profit in this stage. PEA and MEA have to prepare the control system to be a DSO which plays an important role in the future distribution system.

2) At the mature stage

After DR business was started in the market, DR and LA business will become mature. LA will obtain high profit of this business. This market will consist of LA#1 and LA#2 which are established by a utility and a private sector. LA#1 has to have a sufficient group of DRRs and LA#2.

4.1.2.2 Role of future Thailand's electricity sector

Thailand's electricity sector will change its role. LA will be a newcomer in the market. The role of future Thailand's electricity sector is described as follows [25]:

1) Generation

In an ESB era, most of the generation has to sell electricity energy to EGAT. Only very small power producers (VSPPs) can sell electricity energy to PEA/MEA. EGAT is responsible for electrical energy generation and purchase and sell to PEA/MEA.

In the next era, the generation can sell electricity to a utility (EGAT/PEA/MEA) or customers.

2) System Operator/ Transmission System Operator/ Demand Response Control Center

System Operator (SO)/ Transmission System Operator (TSO)/ Demand Response Control Center (DRCC) is one of the key of the electrical market where it has to keep system stability between generation and load. DR is one of the key functions so that SO can keep system stability.

3) Distribution System Operator/ Retailer

In an ESB era, PEA/MEA is distribution utility which is responsible for distribution network and retailer.
In the next era, PEA/MEA is a Distribution System Operator (DSO)/ retailer and private company may be a retailer.

4) Load Aggregator

Load Aggregator: LA which is a newcomer in the energy market is responsible for managing a group of the DRR of DR program in order to reduce maximum demand when calling of utility.

At the beginning stage, PEA/MEA may have LA business unit in the same organization.

At the mature stage, PEA/MEA has to set up a new company of LA business which is separated from main organization. Private company can be a LA.

5) Customer/ Demand Response Resource

A DRR or demand response resource (DRR) of the DR program is a customer who can reduce energy use when a utility calls DR event. The customer can get the benefit of joining the program as capacity payment (CP) and energy payment (EP) as shown in Table 1. CP is an incentive for a DRR which is paid according to reducing electrical demand per kW. EP is an incentive for a DRR which is paid according to reducing electrical energy per kWh.

4.1.3 Thailand's load aggregator business

LA will be a new business in electricity energy market where a group of DRRs is selected, collected and managed in response to the command from a utility. DR business will have LA level 1 and level 2 which have role LA#1 and LA#2 as follows [25]:

1) Load Aggregator Level 1

LA level 1 (LA#1) is the primary level where a LA receives command and sends information between DSO and LA#1 directly. LA#1 pays an incentive that gets from DRCC to a DRR and gets a commission from DRCC. LA#1 has to create an incentive to a DRR who is sufficiently motivated. LA#1 has to pay a fee for meter data of a DRR.

2) Load Aggregator Level 2

LA level 2 (LA#2) is the secondary level where a LA receives command and sends information between LA#1 and LA#2. LA#2 is a group of DRRs that do not large enough to be a LA#1.

4.1.4 Thailand load aggregator business model and structure

Figure 13 and Figure 14 show the route of command, information of metering and verification, and incentive payment among the DRCC, the LA, and the DRR [25].

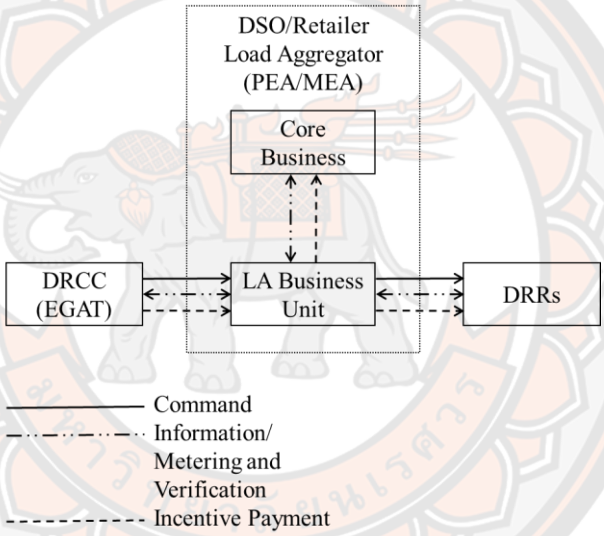

Figure 13 Thailand's LA business model and structure at the beginning stage

At the beginning state, DRCC sends a command to PEA/MEA (LA business unit), then LA business unit uses a LAMS to select a DRR and send a command to a DRR. The DRR has to accept or decline the command.

The information from a DRR sends from a smart meter to LA business unit to measure and verify the reduction of demand of a DRR for an incentive payment. The DRCC receives information from LA business unit to measure and verify the reduction of demand of a group of the DRR of LA business unit.

The incentive will be paid by DRCC to LA business unit. Accordingly, the LA business unit will pay to a DRR. The LA business unit will get the commission from the incentive before LA business pays to the DRR.

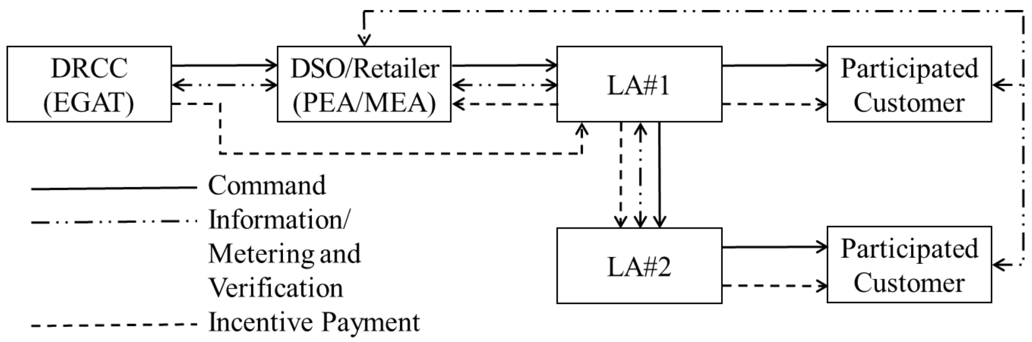

Figure 14 Thailand's LA business model and structure at the mature stage

At the mature state, DRCC sends a command to DSO, then DSO sends a command to LA#1. LA#1 uses a LAMS to select a DRR and/or LA#2 and send a command to a DRR and/or LA#2. The DRR and/or LA#2 has a choice to accept or decline the command.

The information from a DRR is sent from a smart meter to DSO. LA uses information from DSO to measure and verify the reduction of demand of a DRR for an incentive payment. The DRCC gets information from DSO and LA to measure and verify the reduction of demand of a group of the DRR of LA#1 and LA#2. LA#1 has to pay for information usage to DSO.

The incentive will be paid by DRCC to LA#1. Accordingly, the LA#1 will pay to a DRR and/or LA#2. The LA#1 and/or LA#2 unit will get the commission from the incentive before LA#1 and/or LA#2 pays to the DRR.

4.1.5 Thailand load aggregator business organization

In the near future, LA is the new business in Thailand where the utility has to prepare staffs and technologies [25].

At the beginning state, PEA/MEA will be the DSO/Retailer and the LA business will be the business unit under PEA/MEA as shown in Figure 15. The staff and facilities of the LA business unit will be shared from PEA/MEA. The LA business unit will consist of the supporting group and the engineering group under the Director of the LA business unit. The supporting group will consist of the marketing team, the financial team, and the law team. The engineering group will consist of the engineering team, the network operations center (NOC), and the information and communication technology (ICT) team.

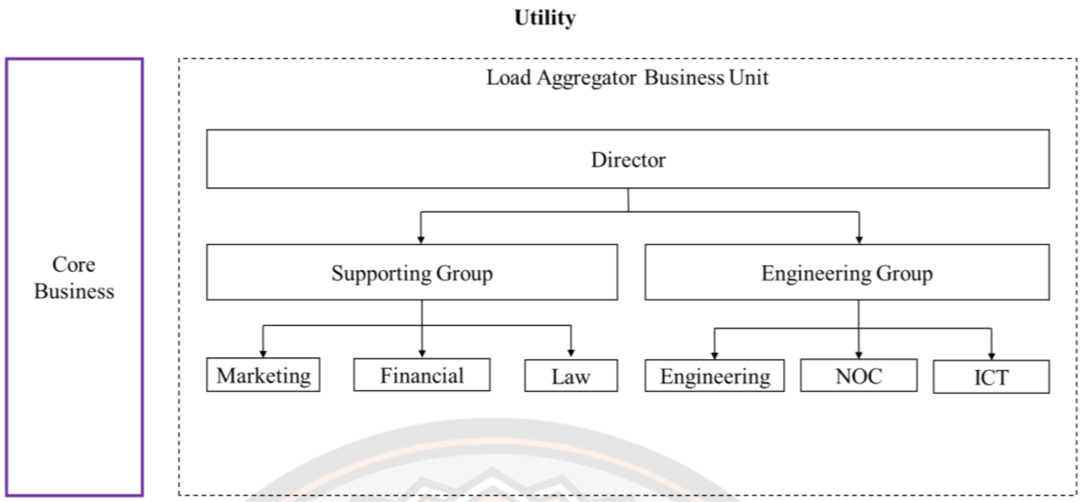

Figure 15 LA business organization of utility at the beginning stage

At the mature state, LA business will separate from PEA/MEA and it will be LA#1 as shown in Figure 16. LA#1 will consist of the supporting group, the marketing group, and the operation group under the CEO's LA#1. The supporting group will consist of the financial team and the law team. The marketing group will consist of the commercial customer team, the industrial customer team, the corporate customer team, and the residential team. The operation group will consist of the engineering team, NOC, and the ICT team.

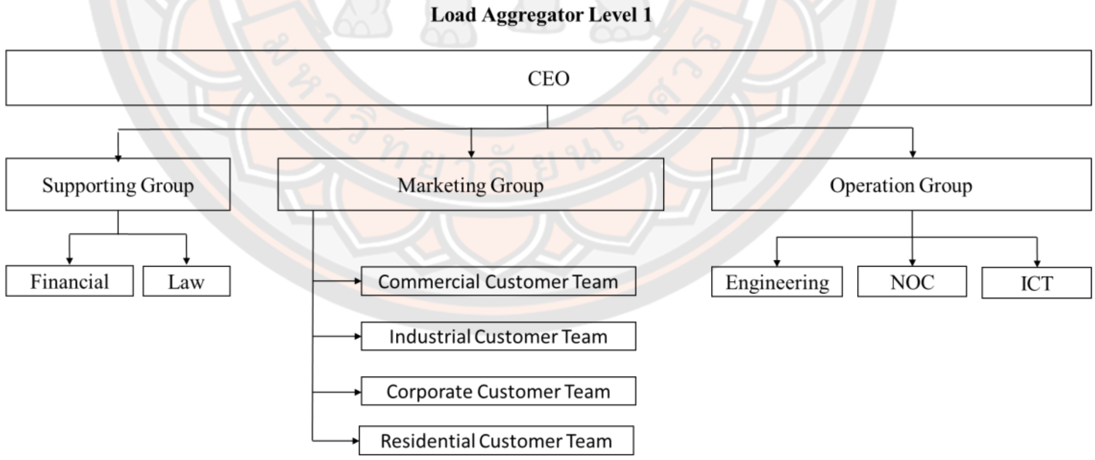

Figure 16 LA business organization of utility at the mature stage

LA#2 is a private sector supporting the small group of the DRR that will be a small company.

4.2 Thailand's DR market size expectation

Peaking power plants are fast response power plants. In this study the peaking power plant is calculated from gas-based generation, diesel generation, and hydro generation. Thailand Power Development Plan 2018-2037 (PDP2018 Revision 1) shows electrical energy demand and generation as shown in Figure 17 [26]. Figure 17 and Figure 18 shows that the orange line is the generation without DR, the dark blue line is the generation with DR, the blue line is demand without DR, the yellow line is demand with DR, and the gray line is possibility peaking power plant, respectively. The electricity is generated by various raw materials such as gas, coal, and renewable energy. The reserve margin between generation and demand is around 30 percent. Peaking power plant and DR are shown in Figure 18. The generation can be defined the peaking power plant which has capacity 14,000-23,000 MW. The DR can be used as the peaking power plant in the beginning stage 500 MW. PDP2018 shows that demand growth at 2.62% - 4.70% and average at 3.15%. This study calculates DR market size expectation at 3%, therefor DR size expectation are 1,400 MW – 2,455 MW by 2021-2037.

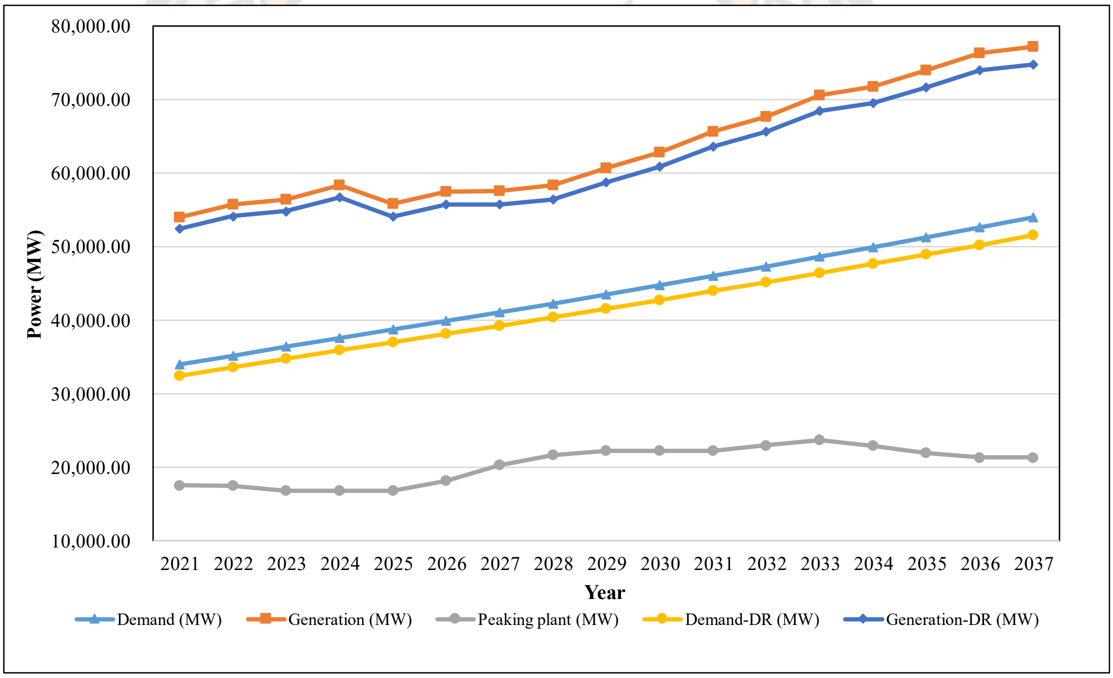

Figure 17 Thailand Power Development Plan 2018-2037 (PDP2018 Revision 1) [26]

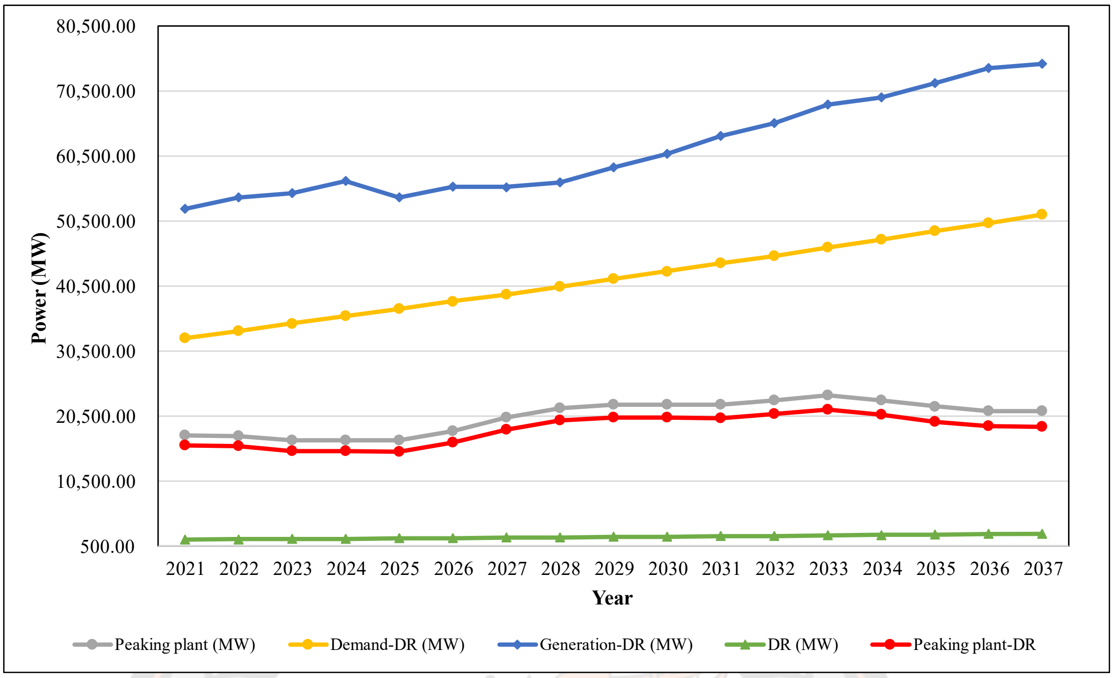

Figure 18 Thailand Power Development Plan 2018-2037 (PDP2018 Revision 1): Peaking power plant and DR [26]

Figure 19 shows that the blue line is the peak demand of 2020, the orange line is the peak demand of 2020 with DR, the green dash line is 95 percent of the maximum demand in 2020 (27.2 GW), and the green line is 95 percent of the maximum demand each month in 2020, respectively. The green dash line and the green line show the possibility DR market size is 1,400 MW that can be used instead of the peaking power plant at 1,400 MW [27].

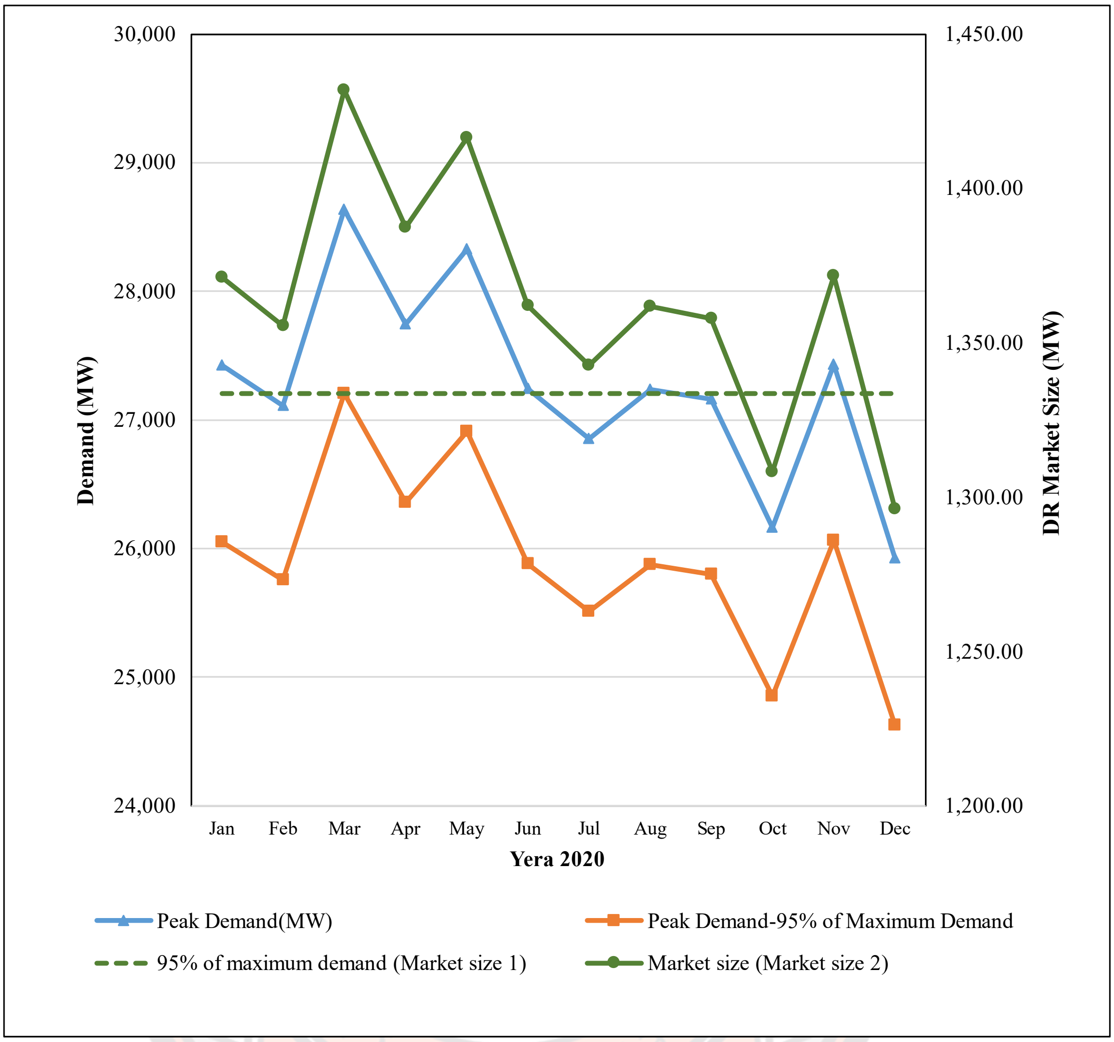

Figure 19 95 percent of the maximum demand of Thailand's 2020 [17]

Table 5 and Table 6 show the present value of costs and benefits of peaking power plant and DR 1,400 MW. Peaking power plant 1,400 MW have a lifetime of 25 years and operate 250 hours/year [17]. Costs of DR are from incentives and benefits from cost saving of fuel of peaking power plant. Assumption of costs and benefits of Peaking Power Plant and DR 1400 MW shown in Table 7.

Table 5 Present value of costs and benefits of Peaking power plant 1,400 MW

Project year	**Cost (M฿)**			**Total cost (M฿)**	**Benefits (M฿)**	**Total benefits (M฿)**	**Grand total (M฿)**
	Investment (M฿)	**Operation (M฿)**	**Maintenance (M฿)**		**Electricity sell (M฿)**		
0	37,800			37,800			-37,800
1		1,081.5	378	1459.5	875	875	-584.5
2		1,081.5	378	1459.5	875	875	-584.5
3		1,081.5	378	1459.5	875	875	-584.5
4		1,081.5	378	1459.5	875	875	-584.5

Project year	Cost (M฿)			Total cost (M฿)	Benefits (M฿)	Total benefits (M฿)	Grand total (M฿)
	Investment (M฿)	Operation (M฿)	Maintenance (M฿)		Electricity sell (M฿)		
5		1,081.5	378	1459.5	875	875	-584.5
6		1,081.5	378	1459.5	875	875	-584.5
7		1,081.5	378	1459.5	875	875	-584.5
8		1,081.5	378	1459.5	875	875	-584.5
9		1,081.5	378	1459.5	875	875	-584.5
10		1,081.5	378	1459.5	875	875	-584.5
11		1,081.5	378	1459.5	875	875	-584.5
12		1,081.5	378	1459.5	875	875	-584.5
13		1,081.5	378	1459.5	875	875	-584.5
14		1,081.5	378	1459.5	875	875	-584.5
15		1,081.5	378	1459.5	875	875	-584.5
16		1,081.5	378	1459.5	875	875	-584.5
17		1,081.5	378	1459.5	875	875	-584.5
18		1,081.5	378	1459.5	875	875	-584.5
19		1,081.5	378	1459.5	875	875	-584.5
20		1,081.5	378	1459.5	875	875	-584.5
21		1,081.5	378	1459.5	875	875	-584.5
22		1,081.5	378	1459.5	875	875	-584.5
23		1,081.5	378	1459.5	875	875	-584.5
24		1,081.5	378	1459.5	875	875	-584.5
25		1,081.5	378	1459.5	875	875	-584.5
NPV (rate 7%)	**41,693.01 M฿**						
IRR	**N/A**						

Table 6 Present value of costs and benefits of DR 1,400 MW

Project year	Cost (M฿)		Total cost (M฿)	Benefits (M฿)	Total benefits (M฿)	Grand total (M฿)
	DR Incentive (AP) (M฿)	DR Incentive (EP) (M฿)		Fuel (M฿)		
0						
1	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
2	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
3	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
4	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
5	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
6	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
7	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
8	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
9	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
10	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98

Project year	Cost (M฿)		Total cost (M฿)	Benefits (M฿)	Total benefits (M฿)	Grand total (M฿)
	DR Incentive (AP) (M฿)	DR Incentive (EP) (M฿)		Fuel (M฿)		
11	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
12	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
13	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
14	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
15	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
16	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
17	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
18	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
19	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
20	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
21	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
22	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
23	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
24	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
25	60	1970.5	2,030.48	1,081.5	1,081.5	-948.98
NPV (rate 7%)	**-10,335.49**					
IRR	**N/A**					

Table 7 Assumption of costs and benefits of Peaking Power Plant and DR 1,400 MW

Item	Detail	Value	Unit
1	Investment cost of peaking power plant [17]	27	M฿/MW
2	Operation cost (Fuel cost) [28]	3.09	฿/kWh
3	Maintenance [17]	1	%
4	Electricity sells [17]	2.50	฿/kWh
5	DR incentive (AP) [16]	42.84	฿/kW
6	DR incentive (EP) [16]	5.63	฿/kWh
7	Benefits of save fuel cost for DR [28]	3.09	฿/kWh

Table 8 shows the comparison of investment between the peaking power plant and DR 1400 MW at a project period of 25 years. Table 8 shows that peaking power plant less present value of costs and benefits than DR, as a result, DR is more cost-effective than peaking power plant.

Table 8 Comparison of present value of costs and benefits between Peaking power plant and DR 1400 MW

Options	Present value of costs and benefits 25 year (M฿)
Peaking power plant	-41,693.41
Demand Response	-10,335.49

Summary of Thailand's DR market size expectation

According to research of Energy Policy and Planning Office, the maximum DR capacity is 1,250 MW [17]. The proposed DR capacity is 1,400 MW which is derived from 5 percent of maximum demand of Thailand's 2020. Thailand's DR capacity target should be achieved 1,400 MW – 2,455 MW by 2018-2037.

4.3 Thailand's DR business model

Thailand's utilities have to analyze the DR business operated by themselves or by private companies. Business analysis tools in this study are SWOT analysis, business model canvas, and financial analysis.

4.3.1 SWOT analysis

The SWOT analysis is tools for analysis the strengths, the weaknesses, the opportunities, and the threats of business that is used in this research.

Table 9 Thailand's utilities SWOT analysis

Strengths	Weaknesses
- Group of customers with strong relationship - Customer database - Strong financial status	- Government process - High operation cost
Opportunities	**Threats**
- Seek and meet target customer from utility database - Customer trust of strong financial status	- LA#1 (Private company) - LA#2 (Private company) - Obstruction of law and policy

Table 9 shows the SWOT analysis of Thailand's utilities composed of strengths, opportunities, weaknesses, and threats of DR business. The details of the SWOT analysis are as follows:

a. Strengths

- o Group of customers with strong relationship

Thailand's utilities have long and strong relationship with customers that they service the electrical to customer.

- o Customer database

Thailand's utilities have all historical of customer that can analyze possibility DRR.

- o Strong financial status

Thailand's utilities are state enterprise that the financial status strong as the Government.

b. Weaknesses

- o Government process

Thailand's utilities are state enterprise that complicate process to service and to make a payment to a DRR.

- o High operation cost

Thailand's utilities are huge organization and complicate responsibility when operate DR business that they may spend more employee and operation cost than small company.

- o Obstruction of law and policy

Thailand's utilities are state enterprise that operate under law and policy that may obstruct to operate fully business as private company.

c. Opportunities

- o Seek and meet target customer from utility database

Thailand's utilities have all historical of customer that can seek and meet possibility DRR.

- o Customer trust of strong financial status

Thailand's utilities are state enterprise that operate under control and has financial guarantee by the Government.

d. Threats

- o LA#1 (Private company)

A private company with strong DRR and experience may give more benefits to DRR that they may have more opportunities to entrance the LA business.

- o LA#2 (Private company)

A private company that can collect a DRR with more benefits may have more opportunities to compete with LA#1 in the LA business.

4.3.2 Business model canvas

This section shows business model canvas of LA business for analysis all activities of all business chain [29]. The details of DR business canvas are as follows:

a. Value proposition

- Strong of customer portfolio
  Thailand's utilities have all historical of customer that can analyze possibility DRR and can category customer portfolio efficiently.
- Consulting and service
  Thailand's utilities have all historical of customer that can analyze customer behavior; so, can suggest the customer to be a DRR.
- More income from DR program

Thailand's utilities have all historical of customer that can analyze customer behavior; so, can suggest the customer to get more benefits from DR program.

b. Customer segment

- Residential Customers
  Residential customer is a house or condominium customer that they are a DRR. Residential customer reduces electricity demand of an appliance such as an air-conditioner, heater, etc.
- Commercial Customers
  Commercial customer is a DRR such as a building, a convince store, a hotel, etc.
  Commercial customer reduces electricity demand of an air-condition, a lighting, etc.
- Industrial Customer
  Industrial customer is a DRR that they reduce electricity demand of their process. Industrial customer is the major DRR in DR business.
- Group of Residential Customers
  Group of Residential Customers is a group of residential customers that they propose to be a DRR with more power and benefits, but they do not prefer to be a LA#2.
- Group of Commercial Customers
  Group of Commercial Customers is a group of commercial customers that they propose to be a DRR with more power and benefits, but they do not prefer to be a LA#2.
- Group of Industrial Customers
  Group of Industrial Customers is a group of industrial customers that they propose to be a DRR with more power and benefits, but they do not prefer to be a LA#2.
- LA#2
  LA#2 is a LA that collects a DRR and operate LA business under LA#1.

c. Channels

- Internet Private Network
  Internet private network is the best channel that it uses for communicating and sending command between DRCC and LA#1 or between LA#1 and LA#2. Internet private network is more secure and stable than normal internet.
- Mobile Application
  Mobile application is powerful channel for real-time interaction between a LA and a DRR.
- Email
  Email is official channel for confirmation between a LA and a DRR that it cheaper than SMS.
- SMS
  Short message is alternative communication between a LA and a DRR.

d. Customer relationship

- Varity of DR program

Variety of DR programs that attract a DRR gain more customer loyalty.

e. Revenue stream

- Commission
  Commission is key revenue of LA#1 that is part of the incentive that the DRCC pay incentive to a DRR.
- Consultant fee
  Consultant fee is revenue of LA#1 that get from a DRR that consult the LA#1 to get more benefits from DR program.
- Service fee for a DRR
  Service fee for a DRR is revenue of LA#1 that get from a DRR that install equipment of a DRR.
- Service fee for LA#2
  Service fee for LA#2 is revenue of LA#1 that get from a LA#2 that service LAMS.

f. Key resource

- Smart meter
  Smart meter is key resource for measuring and verification of DR program for settlement to a DRR and LA#2 that it is service by DSO.
- LAMS
  LAMS is system that use for control and calculate DR program among DRCC, LA#1, LA#2, and a DRR.

g. Key activities

- Enroll customers
  LA#1 enroll customer to be a DRR.
- Enroll LA#2
  LA#1 enroll LA#2 to be LA#2 under LA#1.
- Customer consulting
  LA#1 give a suggestion to DRR for DR program.
- Call DR program
  LA#1 call DR program to DRR and LA#2 to participate DR event from DRCC.
- Verification
  LA#1 verify electricity reduction of DRR for the settlement.
- Settlement/ Payment
  LA#1 calculate electricity reduction of DRR for the settlement and make a payment to DRR and LA#2.

h. Key partners

- DRCC/DRMS (EGAT)
  DRCC/DRMS is VTN that call DR program by sending command and pay incentive to a DRR via LA#1.
- DSO (PEA)
  DSO is distribution operator (PEA/MEA) that maintain distribution system. DSO receive DR command from DRCC then send command to LA#1. DSO operate MDMS and service metering data of a DRR to LA#1 and LA#2.
- Energy Regulatory Commission (ERC)

ERC are responsible to regulate Thailand's utilities. ERC create DR program of DR business.

- Energy Policy and Planning Office (EPPO)
  EPPO is the government organization that create Thailand's energy policies. EPPO create policy of DR and driven DR policy.
- Air-condition Company
  Air-condition is the most electricity usage in Thailand's household. Air-condition can be embedded the OpenADR communication device with air-condition that DRR can be ready to participate in DR program.
- Smart Device Company
  Smart device with home gateway or smart device with API application that can interface with LAMS can be ready to participate in DR program.
- Energy Management Company
  Energy management company is key partner that they install the energy management system (EMS) for the commercial and industrial customer. The EMS that supports OpenADR protocol can be ready to participate in DR program.
- Residential developer
  LA#1 can persuade the residential developer to build new home that equip with air-condition and smart device that support OpenADR protocol. The residential developer can be LA#2 or a group of residential customers to participate in DR program.

i. Cost structure

- Cost of metering and infrastructure
  LA#1 install additional meter for real-time measurement that support fast DR program. LA#1 use communication media from service provider to communicate with DRCC, a DRR, LA#2, air-condition company, and smart device company.
- Operation cost
  Operation cost is the cost of personal, maintenance, and transportation cost that LA#1 spend to operate LA business.
- Service fee for metering data from DSO
  LA#1 use metering data for measurement and verification that provide by DSO.
- Promotion cost
  Promotion cost is the cost that LA#1 spend to persuade a DRR to participate or continue with LA#1.
- Facilities cost
  Facilities cost is the cost that LA#1 spend facilities to operate LA business such as office rental cost, utilities cost, etc.

4.4 Financial Analysis

Figure 20 shows Thailand's LA business model and structure that the incentive paid by DRCC to LA#1 [25]. Then the LA#1 pays the incentive to a DRR and/or LA#2. The LA#1 and LA#2 receive income from the commission of the incentive.

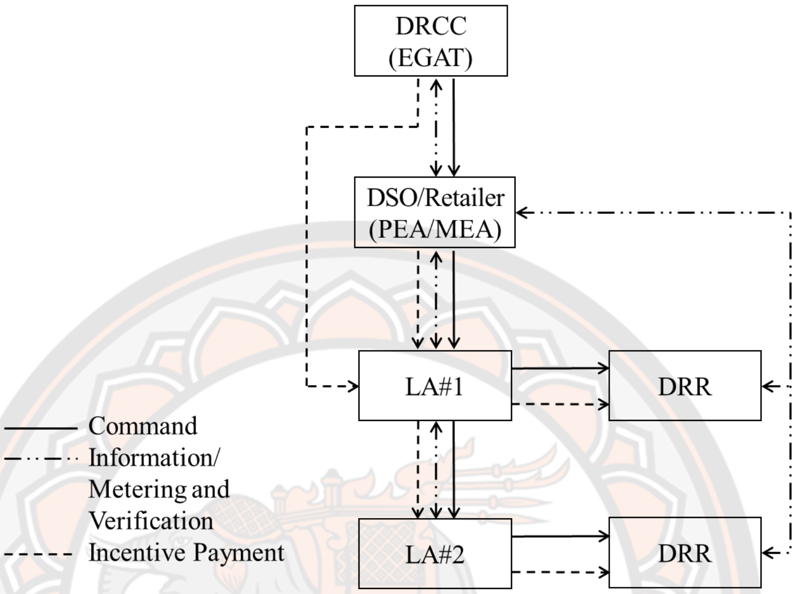

Figure 20 Thailand's LA business model and structure [25]

Table 10 Assumption of Financial Analysis

Item	Detail	Value	Unit
1	Server and software [30]	1,340	M฿
2	Communication	55,000	฿/month
3	Metering fee	10	฿/meter/month
4	Personal	808,000	฿/month
5	Facilities	141,000	฿/month
6	Maintenance	5	%
7	Promotion	50,000	฿/month
8	Transportation	500,000	฿/month
9	Commission from DRCC (CP DLC) @100 MW [16]	15.42	M฿
10	Commission from DRCC (CP DLC) @100 MW [16]	7.71	M฿
11	Commission from DRCC (EP) @900 MW [16]	273.62	M฿
12	Consultant fee @ 2,000 DRR	500	฿/month/DRR

The details of costs and benefits of LA#1 in Table 10 shown as follow:

a. Cost of LA#1 are as follow:

- Server and software cost are investment cost of server and LAMS software that have two system (main and back up) it can support DRR more than 1,400 MW. Server and software cost is 1,340 million baht for ten years [30].
- Communication cost are cost of the internet 15,000 baht/month, lease line from DRCC to LA#1 20,00 baht/month, mail server service 20,000 baht/month.
- Metering fee is cost of metering data that provide by DSO 10 baht/meter/month
- Personal cost is cost of LA#1's staff that compose of management team for 5 persons, engineering team for 8 persons, marketing team for 4 persons, technical team for 8 persons, and supporting team for 4 persons. Personal cost is 808,000 baht/month with 3% increments each year.
- Facilities cost is rental cost of office and utilities cost that is 141,000 baht/month.
- Maintenance cost for LAMS is five percent of investment cost that is 67 million baht/year.
- Promotion cost is cost that LA#1 spend to persuade a DRR to participate or continue with LA#1. Promotion cost is 50,000 baht/month.
- Transportation cost is traveling cost for LA#1's staff to service a DRR. Transportation cost is 500,000 baht/month.

b. Benefits of LA#1 are as follow:

- Commission from DRCC from Availability Price (AP) of DLC#1 program is calculate by 30%x100 kW/DRR x 1,000 DRR x 42.84 baht/kW [16].
- Commission from DRCC from AP of DLC#2 program is calculate by 30%x100 kW/DRR x 1,000 DRR x 21.42 baht/kW [16].
- Commission from DRCC from Energy Price (EP) of EDRP program is calculate by 30%x300 kWh/DRR x 3 hr. x 5 times/month x 1,000 DRR x 5.63 baht/kWh [16].

Net present value (NPV) and internal rate of return (IRR) are indicators that can operate the business. Net present value (NPV) greater than zero means that the business gets profit. Investment of the government, the internal rate of return (IRR) is more than 7%. For the private sector, the internal rate of return is more than 12%. However, when considering the investment, the return on investment may be greater or lower than 12% depending on the business model.

The financial analysis of LA business shown in Table 11 is derived from investment cost of LAMS [30], communication, metering fee by DSO, personal, facilities, maintenance, promotion, and transportation. The benefits of LA#1 originate from commissions that are 30% of CP and EP as shown in Table 1 [16]. Table 11 shows that NPV of LA#1 is 175.43 M฿ and 10% of IRR.

Table 11 LA#1 Financial Analysis

Project year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cost (M฿)											
Server and software	1,340.00	-	-	-	-	-	-	-	-	-	-
Communication	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Metering fee	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Personal	9.70	9.99	10.29	10.60	10.91	11.24	11.58	11.92	12.28	12.65	13.03
Facilities	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69
Maintenance		67.00	67.00	67.00	67.00	67.00	67.00	67.00	67.00	67.00	67.00
Promotion	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Transportation	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Total cost	**1359.85**	**87.14**	**87.44**	**87.75**	**88.06**	**88.39**	**88.73**	**89.08**	**89.43**	**89.80**	**90.18**
Benefits (M฿)											
Commission from DRCC (CP DLC)		15.42	15.42	15.42	15.42	15.42	15.42	15.42	15.42	15.42	15.42
Commission from DRCC (CP DLC)		7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71
Commission from DRCC (EP EDRP)		273.62	273.62	273.62	273.62	273.62	273.62	273.62	273.62	273.62	273.62
Consultant fee		12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Total benefits	**0.00**	**308.75**	**308.75**	**308.75**	**308.75**	**308.75**	**308.75**	**308.75**	**308.75**	**308.75**	**308.75**
Grand total	**-1359.85**	**221.61**	**221.31**	**221.00**	**220.69**	**220.36**	**220.02**	**219.67**	**219.32**	**218.95**	**218.57**
NPV (rate 7%)		**175.43 M฿**									
IRR		**10%**									

CHAPTER 5 CONCLUSION

5.1 Conclusion

DR is a dynamic change in electrical demand from normal patterns in a specific period that responds to the price or incentive of a utility signal to suggest a DRR to reduce electrical demand during a period of peak demand to secure the electrical system. This study presents the business solution for DR in Thailand for Thailand's utilities and policymakers. The key success factor in the DR business is DRR collection by a LA. Furthermore, the future energy market, the future DR business, LA organization, the new role of future DR energy market in the future energy market composed of SO, TSO, DRCC, DSO, LA#1, LA#2, and DRR, the DR market size expectation, the SWOT analysis, the business model canvas, and the LA#1 financial analysis for the development of LA#1 business solution in Thailand's energy market are proposed.

In the near future, Thailand energy market will change from ESB into the energy market or the power pool market, so will each other country market such as United stated of America and South Republic of Korea. In Thailand, the energy market which may be different from other counties have three key utilities (EGAT, MEA, and PEA). Newcomers, LAs, energy market operators, and prosumers will change a role of Thailand's energy sector. EGAT will change a role from generation and transmission into generation, SO, TSO, and DRCC. PEA and MEA will change a role from distribution and retailer into DSO, retailer, and LA#1. The customer will become the prosumer, consumer and producer. DR will be a key function of the future electrical energy market where it will be used for system security instead of a peaking power plant. LA will be a new business where a group of DRRs is selected, collected and managed as requested by DRCC. LA is a key success factor of DR business because it has to select, collect and manage quality of a DRR in response to DR program. However, a DRR can choose a LA offering reasonable incentive and having highly efficient management profile. PEA and MEA have an opportunity to be an LA#1 in order that PEA and MEA have a good relationship with customers; otherwise, they may lose some margin when DR is called by DRCC.

Thailand's DR market size expectation is 1.4 GW – 2.5 GW by 2021-2037 which DR can replace the peaking power plant. The SWOT analysis shows the strengths and opportunities of Thailand's utilities on DR business more than that of the private sector. The business model canvas shows activities related to LA#1 management on the LA business. LA#1 gets income from the commission of CP and EP paid by DRCC. DR programs managed by LA#1 are DLC and EDRP. The incomes of LA#1 are 30 percent of incentive paid to DRR by DRCC and consulting fee for a DRR. LA#1 invests in infrastructure cost and pays monthly operation cost as shown in Table 7. The financial analysis shows that NPV and IRR of LA#1 are 175.43 M฿ and 10 percent, respectively. LA#1 can get more benefits by reducing the investment and operation cost and by receiving more incomes by the service the LAMS to LA#2.

Finally, Thailand utilities have to improve their electrical system using smart grid technology so that their power system will be modernized. DR is one of the key technologies that reduce electricity usage in the high-demand period that can reduce investment costs in the generation, transmission, and distribution system. Moreover, the LA business is a new business of Thailand’s energy market which LA can manage DRR of the DR market. Furthermore, DR plays an important role in the electrical network provided by Thailand’s utilities so that their electrical system will be modernized by using smart grid technology.

5.2 Recommendation

1. Further study should be done on DRCC and LA#2 financial analysis.
2. Study more on LA business such as DR for EV, ESS, etc.

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