Thailand smart grid adoption in residential electricity consumer

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Abstract

Smart grid technology is one of the advanced technologies in the present world of electrical energy management so as to increase its efficiency through the combination of the information and communication technology (ICT), and the transmission grids leading to the information exchange in real time. The consumer's adoption of this technology is important to the success in presenting it to the public. However, many studies have investigated the consumer's comprehension and adoption of the smart grid technology. This research adopted the most famous models, called Technology Acceptance Model: TAM and Value Based Adoption Model: VAM, which was created based on the concepts of the smart grid adoption from many theories and models such as diffusion of innovation theory, motivation model, social cognitive theory, perceived risk and the smart grid technology concepts. This study aimed to investigate a hybrid model created from the mentioned theories and models by determining the variables affected by the acceptance and the variance of the smart grid technology of the consumers. These issues might affect the customer's decision concerning this innovative technology. This research showed that the factor variables affecting the adoption of smart grid technology were four internal factor variables from high to low; benefit of application, ease of application, value of application and risk of application. The design of application content and menu should be easy to apply and understand with no background or involved knowledge. The research results can be beneficial to regulators, policymakers, system designers and technology developers such as smart grid provider and smart grid system-supporting appliance manufacturers via the development from the consumer's perspective and demand.

Keyword: *Smart grid technology, technology acceptance model, smart grid acceptance, customer acceptance*

1. Introduction

Nowadays, smart grid technology is one of the advanced technologies and is supposed to be the technology for

the future to increase the efficiency of electricity management. The principle of the smart grid is the combination of information and communication technology integrated with the transmission line leading to information exchange in real time between a supplier and a consumer. As a result, the customer can manage his own electricity consumption and the bill. Furthermore, smart grid technology has its electricity-generating management from an alternative source, which is unable to generate the amount of the energy constantly, to have more efficiency in energy production [1]. Its principle is that the electricity allocation has to fit the customer's demand and reduce the peak of electricity consumption each day [2].

The smart grid application has become widely well-known in Thailand since the power development plan of Thailand 2015 (PDP 2015) by promoting investment in the smart grid system infrastructure in country [3] and the Ministry of Energy has formed the master plan to develop a smart grid [4] and has launched the smart grid pilot project in Thailand. However, smart grid technology is very useful in increasing the efficiency of using the electricity and being integrated with renewable energy to generate the electricity but it is quite new to the customers in the adoption of it.

Public acceptance is essential to the success in presenting it to society. However, many previous studies conducted a survey on smart grid acceptance. Most of the studies aimed at the

limitation of the factors but not covering the important factor framework affecting public acceptance of this technology. The feasibility of the survey on the smart grid understanding of the consumers by applying the various theories and models from reviewing the related articles towards the explanation of the technology acceptance [5]. The first and most important thing is to understand the consumers about what has an impact on their opinions and behaviors. Then, the survey on the possibility of the factors the smart grid technology acceptance at the significant difference. From various theories and models of the technology acceptance, it could be seen in the research from different fields such as Information System, Psychology and Social Science. The well-known model, applied in this research, is the Technology Acceptance Model: TAM which is widely used and accepted in the field of information technology, a basic structure of a smart grid system [6] is combined with the theories and models such as diffusion of innovation theory, social cognitive theory, motivation theory model [7].

The aim of this study was to propose a new hybrid model created from various models and theories related to the acceptance of smart grid technology by determining the variables affecting the consumer's acceptance and variance which had an impact on the consumer's decision of innovative technology. The study results would be the information for regulators, policymakers, system designers and technology developers such as a smart grid provider and smart grid system-supporting appliance manufacturers via the development from the consumer's perspective and demand.

2. Research methodology

This research aimed to study the use of the document analysis process by presenting the research hypothesis and the theoretical –simulated model in studying the acceptance of smart grid technology and the customer's acceptance and adoption in Thailand via the use of theory and simulated model. Here are the research processes. Participants in this research were 500 electricity consumers of Provincial Electricity Authority (PEA) from 4 regions, selected by using Yamane's ready-made table at the reliability level of 95 percent. Data collection used a total of 500 respondents who were participating in this research. The respondent were the users of electricity form the Provincial Electricity Authority (PEA) of Thailand, who were either residential, business, industrial or governors. All respondents completed the same questionnaire,

The representation of the fourteenth latent variables of smart grid technology acceptance and adoption. All the observed questions of latent variables were measured in 7-point Linkert scale, ranging from 1 "I strongly disagree" to 7 "I strongly agree". The questionnaires were distributed from October 2016 to March 2017. During that period, 500 questionnaires were collected and use throughout our analysis. Defining variables involved with smart grid technology acceptance. Synthesizing and analyzing documents, texts, journals, articles and previous related studies concerning the technology and smart grid acceptance from the data base of Science Direct, IEEE Explore and Springer. Taking the conclusion from the content analysis to establish the research - hypothesized variables and the logical relation model on smart grid technology acceptance. Concluding the theoretical - simulated model and the hypothesis gained from the concepts on the simulated model and the related theories of smart grid technology acceptance. The data analyzing procedure on structural equation model of smart grid technology acceptance. Collecting and analyzing manipulated and complete data. The analyzing factors to certify the variable factors by a means of confirmatory factor analysis and analyzing the logical correlation of smart grid technology acceptance through path analysis [8].

3. Results

3.1 Variable determination

The result on the variable determination involved with the acceptance and adoption of smart grid technology. The results indicated that there were 14 factors affecting the consumer's acceptance and adoption of smart grid technology in Thailand : four internal variables; ease , usefulness, value and risk of application, and ten external variables; complexity of application, accordance with conventional technology, understanding of application, environmental impact,

content, menu and form of the program, pleasure of application, technique feature, personal internet and information safety, radiation of electric magnet and equipment efficiency.

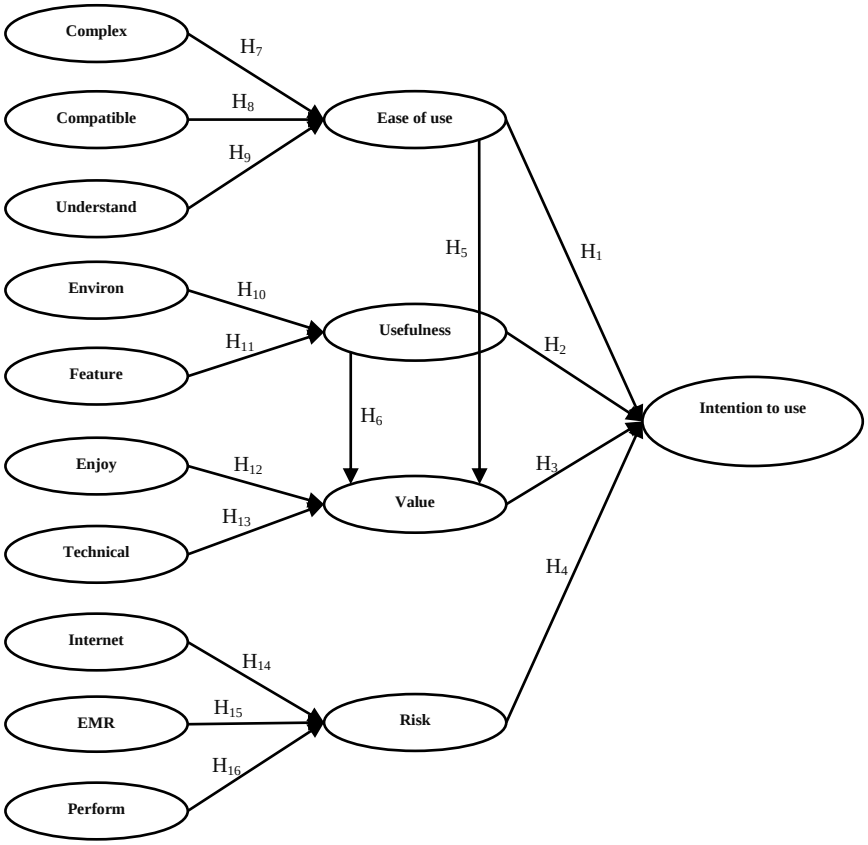
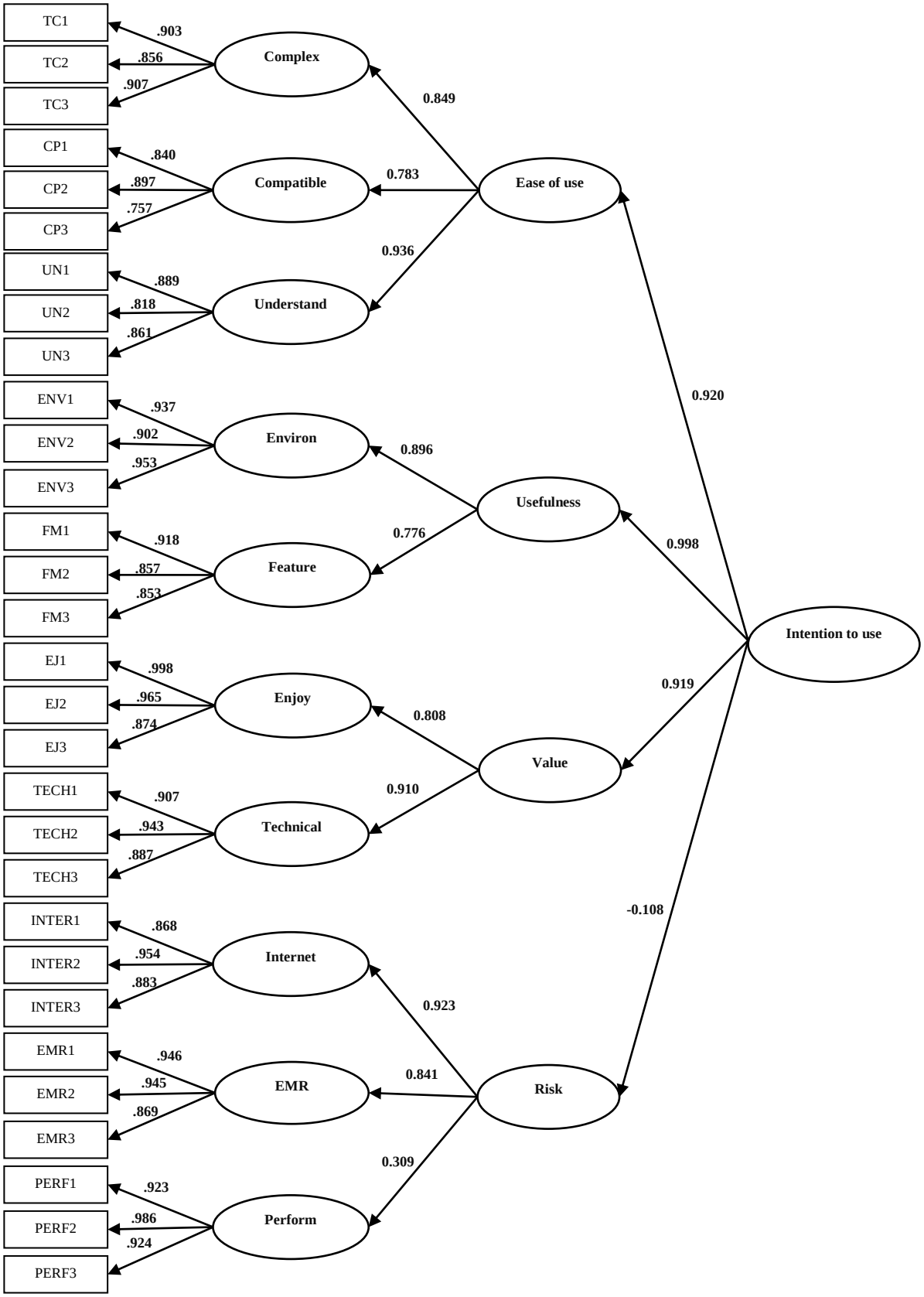


Figure 1 the proposed hybrid smart grid acceptance model
Source: Original research

3.2 Confirmatory factor analysis

This analysis aimed to confirm the visible and invisible variables which were consistent with each other and order the invisible variables towards technology acceptance. From the analysis on third order confirmatory factor, it was found that the statistical chi-square was at 288.872 and of no statistical significance (p7.05) at 0.606, χ^2/df at 0.97, GFI index 0.964, AGFI index at 0.944, CFI index at 1.000 meanwhile standard RMR at 0.045 and RMSEA at 0.000. All statistical values passed the criteria. This indicated that the model was congruent with the empirical data as shown in Fig. 2.



p-value=0.606, Chi-Square=288.872, df=296, RMSEA=0.000

Figure 2 illustrating the result of third order confirmatory factor analysis
Source: Original research

Table 1 Result on the third order confirmation factor of smart grid technology acceptance.

Factor variable	Standardized Factor Loading	R^2
COMPELX<------EASE	0.849	0.721
COMPATIBEL<------EASE	0.783	0.613
UNDERSTAND<-------EASE	0.936	0.876
ENVIRON<------USEFULNESS	0.896	0.603
FEATURE<------USEFULNESS	0.776	0.803
ENJOY<------VALUE	0.808	0.653
TECHNICAL<------VALUE	0.910	0.829
INTERNET<-------RISK	0.923	0.852
EMR<-------RISK	0.841	0.707
PERFORM<-------RISK	0.309	0.069
EASE<-------INTENTION	0.920	0.847
USEFULNESS<------INTENTION	0.998	0.901
VALUE<------INTENTION	0.919	0.844
RISK<------INTENTION	-0.108	0.012

Source: Original research

Table 1 shows the result on the third order confirmation factor of smart grid technology acceptance, it was revealed that the variable factors had a factor weight between -0.108 and 0.998 and standard deviation explains the variable was between 1.2 and 10.1 percent.

3.3 Analyzing the logical correlation

The analysis results of the factor variables affected the adoption of smart grid technology by calculating the effect coefficient value.

Factors on the adoption of smart grid technology are listed below in descending order, the first is the benefit of application (.890), followed by understanding of application (.579), value of application (.468), complexity of application (.433),equipment efficiency (.325), ease of application (.289), environmental impact (.258), accordance with conventional technology (.191), content, menu and form of the program (.161), enjoyment of application (.112) and technique feature (.068), respectively. The eleven variable factors contributed to predict the adoption of smart grid technology by 52 percent as show in Fig. 3.

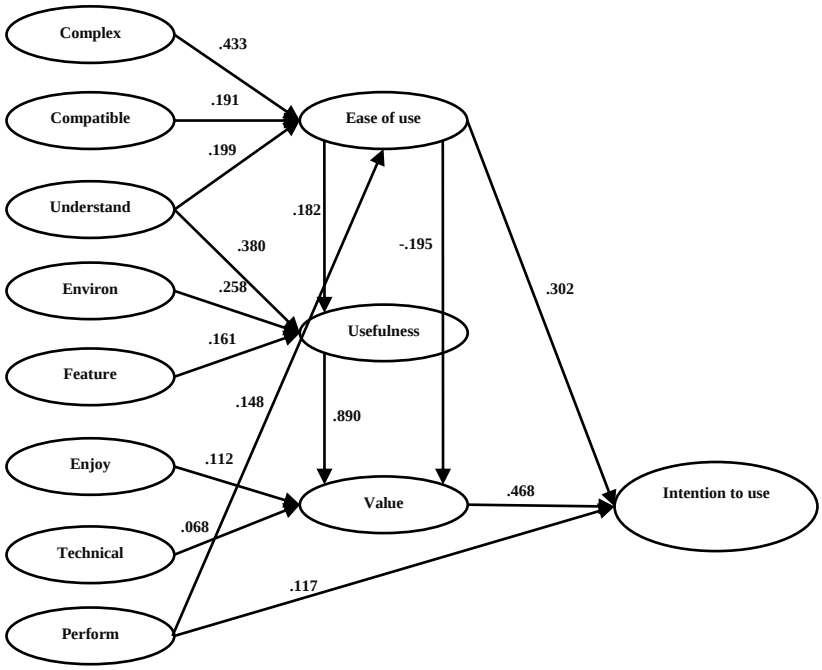


Figure 3 illustrating cause correlation model of the adoption of smart grid technology
Source: Original research

4. Discussion

From the research, it could be concluded and discussed that factor variables affecting the adoption of smart grid technology were four internal factor variables from high to low; benefit of application, ease of application, value of application and risk of application which were congruent with Fairus's studied Technology Acceptance Model; Empowering the Customers to Participate in Electricity Supply Systems concerning suggestions that benefit the application, ease of application and risk of application were factor variables of smart grid technology acceptance and help to increase the customers' participation in smart grid technology since they recognized that they could gain benefits from technology application [9], along with Kim, et.al proposed the Value-Based Adoption Model: VAM in their research: Value-Based Adoption of Mobile Internet by identifying that the highest value perception would result in more technology application. Meanwhile, there were ten external factor variables; understanding of application, internet and personal information safety, technique feature, content, menu and form of the program, complexity of application, electric magnet radiation, enjoyment of application, accordance of traditional technology, environmental effect and equipment efficiency [10] which were in accordance with Chan, et.al in finding that understanding of an application would help increase more attention of an application [5]. In accordance with Jui, et.al on the study of the Development of Indicators to Measure the Customer's Habit and Behavior towards the Application of Domestic Smart Meter , it was found that internet and personal information safety, technique feature, content menu and the form of the program and complexity of the application were the variables promoting the application of smart grid technology [6] which was in line with Ellabban and Abu-Rub concerning the Customer's Engagement and Adoption of Smart Grid Technology: An Overview, indicated that the impact on the environment was the result from the external factor of the customer's adoption of smart grid technology [11].

From the study about the relationship between the different internal factors of smart grid technology acceptance model, it was revealed that the factors of smart grid technology acceptance that gained the highest total effect were, benefit of application, value of application, complexity of

application, equipment efficiency, ease of application, environmental effect, accordance with traditional technology, content, menu and from of the program, enjoyment of the application and the lowest level was technique feature. It can be obviously concluded that the users emphasized the benefit of technology applications such as the benefit of the efficient increase of power consumption and the decrease of expenses from electricity consumption, ease of application, no complexity of an application, reliable and efficient equipment, measuring accuracy and equipment lifespan. The design of application content and menu should be easy to apply and understand with no background or involved knowledge, for example, the domestic monitor should be designed to be easy to read and understand all figures or numbers that appear, and the user could enjoy during the application. Also, all its components should be friendly to the environment as currently people pay attention to the environmental impact which is consistent with Fairus's study Technology Acceptance Model (TAM); The Ability to Increase Consumer Participation of the Electricity Supply[9], and Chan, et.al: Factors Promoting Consumer Participation in Smart Grid technology Application [5] as well as Yunus, et.al: Consumer Participation towards Smart Grid Supply [2] as well as Krishnamurti, et.al: The Readiness Preparation for Smart Grid Technology; Understanding the user need of Smart Meters [12] and Stragier, et.al: The Perception of the Consumer of Smart Grid Domestic Device [13].

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