The Efficient Forecast of Demand Side Management for Flight Simulator Energy Management System

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Abstract : This study aims to investigate the efficiency of the utilization of renewable energy, which plays a significant role in developing energy assurance and preventing the blackout damage to the Royal Thai Air Force (RTAF) flight simulator facility equivalent to that of the fighter F-22 of U.S. demonstrates. The United State Air National Guard has already applied the research of microgrid and Building Energy Management System (BEMS) to supply energy independently into its flight simulator system. However, this research's dissimilar environments are energy demand, microgrid location, Global Horizon Irradiation (GHI), and weather conditions, which affect the microgrid proficiency performs differently. In addition, ensuring the efficiency of energy-enabled and safe, the key to success for energy planning and management is the Efficiency Forecast of Demand Side Management (DSM) design for isolating the main grid's preliminary problem and increasing the cyber security level of RTAF energy. Consequently, the researcher selects the HOMER Pro® Microgrid Software, which is one of the global commercial microgrid standards for energy modeling tools and other distributed energy projects to simulate the DSM forecast to evaluate the microgrid design in Nanogrid level.

Keywords : Demand Side Management, Nanogrid, Smart Grid, Zero Net Energy

1. Introduction

In the last decades, “Energy supplies are never enough”, more and more stress is put on the electricity supply and infrastructure by increasing of energy demand. The evidence in Thailand has shown that the electricity demand trend has continued to increase during the last 10 years. More energy efficiency is believed to be the key reason behind the slow growth of electricity demand compared to the economic growth rate [1]. In the same way, the Electricity Generating Authority of Thailand (EGAT) has reported the Gross Energy Generation and Purchase (by Type of Fuel) [2] that outlook described the purchased supply trend increased from 88,496.04 Million kWh/year in 2011 to 121,233.72 Million kWh/year in 2016 and reduced to 94,957.46 Million kWh/year in 2017 due to the increase of the EGAT’s Gross Energy Generation.

Consequently, from the fact above, the Royal Thai Air Force (RTAF) has been aware of instability of energy security. The challenge is how maintain the RTAF operational readiness in the Humanitarian Assistance and Disaster Relief (HADR) mission when on-grid system is unable to provide the electrical power resources. In 2016, the decision was made to initiate the change of strategic energy management from the old-fashioned “Build and Connect” to the “Connect and Manage” concept [3] by implementing smart grid technology. In addition, reviewing the RTAF Energy Strategic Plan 2010-2025 with attaching the supplement of smart grid project [4], and launching the RTAF smart grid’s academic to the RTAF Energy committee and staff during the smart grid seminar on 20 June, 2018 [5]. The flight simulator building of wing 7 Surat Thani was selected for the smart grid’s demonstration site in Building Energy Management System (BEMS) level. The problem of this building was reported that its equipment was damaged frequently, resulting from blackout and brownout findings.

According to the studies of the demonstrated sustainable microgrid power station and BEMS Concept from the United State Air Force F-22 flight simulator building at Joint Base Pearl Harbor Hickam, Hawaii [6], the solution of the energy problem is to provide on-site energy sources, including fuel and solar power, making up a majority of energy demand-side management. So, microgrids allow power to be stored and distributed directly to the end-user (Flight Simulator), instead of going through a large interconnected network of energy systems. In turn, microgrids offer a more resilient energy source, resistant to weather and external attacks, both physical and cyber-related. From existed solution, this research referred to the similar microgrid concept by installing the additional on-grid 43 kW Nanogrid (The Microgrid level is 50 kW and below) [7] and integrating with AMI, and EMS control application. Before procuring the system for installation, the researcher used The HOMER Pro® Microgrid Software to evaluate the efficient forecasting of Demand Side Management (DSM) and the reliability of BEMS to ensure the EMS meets the desired demand response criteria.

The research methodologies of DSM approach are applied from the cost-effective trade-off based renewable power augmented energy efficient load model for the DSM of the manufacturing industries [8], and the design technic of a Hybrid AC/DC Microgrid Using HOMER Pro: Case Study on an Islanded Residential Application [9]

2. Objectives

The objectives of the study are

2.1 Creating more redundant energy reliability in order to secure the flight simulator system as well as to the flight simulator from the blackout/brownout damage with smart grid technology,

2.2 Implementing the Nanogrid concept into the BEMS network as The RTAF pilot project, and

2.3 Developing the RTAF renewable strategy and the RTAF cyber security policy to interoperate with Network Centric Operations (NCOs) Concept by the capability of real-time monitoring.

3. Definitions

Demand Response (DR) [10] : The demand response provides an opportunity for consumers to play a significant role in the operation of the electric grid by reducing or shifting their electricity usage criteria. Demand response programs are being used by some electrical system planners and operators, as resource options for balancing supply and demand.

Demand Side Management (DSM) [11] : The control or influence of end-users' energy consumption, typically at times of peak demand on the network.

Efficiency Forecast [12] : The forecast analysis of the electrical produce effectiveness of efficiency measures that are simulated yearly performance by HOMER Pro® Microgrid Software.

4. Scopes

For a smart grid's successful introduction, the developers will face a number of technical challenges [13]. To improve better monitored and managed grid, a so-called “Smart grid”, we need to consider five key technologies required for the smart grid as follows: 1) Sensing and measurement, 2) Integrating communications, 3) Advance components, 4) Improve interfaces and decision support, and 5) Advanced Control. In this research, the researcher focuses on the Areas of Sensing and Measurement, and Decision support only. Because the demonstration site is located inside the airport area (Airside), the developer shall concern the additional design factor that shall not affect the flight safety.

4.1 Location of Demonstration Site

The Flight Simulator Building at RTAF Wing 7 Air base [14] located on LAT-LONG N 09° 08.2’ 99 08.2’E, Surat Thani province in the southern territory of Thailand. The Global Horizon Irradiation (GHI) [15] values approximately 1750-1800 kWh/ m^2 [16]. The limitation of the research is the lack of the potential PV electricity production (PVOUT) information due to no explicit reference [17].

4.2 Flight Safety Factor

The critical flight safety factor is the environmental factor. For flight safety reasons, The FAA recommended the Reflectivity of Photovoltaic (PV) Retrofitted Panels [18] be one the most critical factors to flight safety. According to researchers at Sandia National Lab, when light is reflected off from the surfaces, that risks are glint and glare can cause pilots or air traffic controllers the loss of vision, also known as “Flash blindness” for a period of 4-12 seconds. This occurs when 7-11 W/m^2 (or 650-1,100 Lumens/m^2) reaches the eye [19]

4.3 PV directional installation technic

Based on 4.2, the installation of the Solar PV Retrofitted is compulsory to offset from facing south. The reason is to prevent the pilot glare effect during takeoff and landing. According to the environmental factor, the Surat Thani airport has the runway alignment on axis 42.4° and 222.4° which resembles the RTAF simulator building’s alignment direction. Therefore, the Solar 43 kW PV rooftop is tilted angle between installed 10-18 degrees from horizon axis with the maximum best angle to absorb the solar irradiation and offsetting from south to west 42.4° (no facing south directly).

5. Methodology

The steps of methodology are as follows:

Firstly, the primary load by the Demand Response Assessment and set prioritization are defined because the nature of renewable energy is unpredictable and inflexible. Therefore, the 40 kW microgrid is unable to support the whole load of the building, it is necessary to prioritize and manage the energy distribution.

Secondly, the microgrid infrastructure and Demand Side Management (DSM) are defined. This research is simulated to install the Solar PV rooftop microgrid on the flight simulator building because there is no space for installing solar farms. Creating the microgrid infrastructure and network with The HOMER Pro® Microgrid Software.

Lastly, the required data is processed into the software, followed by the execution of the simulation of DSM efficiency forecasting, analysis and evaluation.

5.1 The Demand Response (DR) Assessment and Prioritization

The survey of DR identification is shown as *Table 1-Demand Response Assessment.* The Prioritize sets of DSM are DR#1 Flight Simulator unit (16 kW), DR#2 Data Server (15 kW), and the lower priority for the rest.

Table 1 Demand Response Assessment

DR Priority	Meter Monitoring		Load consumption kW (Actual Load)	Transformer kVA	Electrical back up			Remarks
	Brand	Model			Electric Generator kW	Power UPS kW	Solar Cell kW	
1. Simulator Unit	Schneider	PM-800	16					DR#1 and DR#2 are connected with islanded microgrid stability
2. Simulator Building	Schneider	PM-800						
2.1 Data Server			15					
2.2 Office			40			120		
3. 701 Office	Schneider	PM-800	34	800	500			
4. 702 Office	Schneider	PM-800	25					
5. 701 Maintenance	Schneider	PM-800	193			-		
6. 702 Maintenance	ENTES	MPR50	64	500	-	-		

5.2 Nanogrid Design

The design concept is the hybrid Nanogrid that integrated with Solar 40 kW PV rooftop, 120 KVA UPS battery backup, and 800 kW diesel gas generators with the islanded mode capability during office hour (8 am – 4 pm) as shown in Figure 1. The Nanogrid algorithms are; a) when on-grid condition and daytime, the tasks of 40 kW PV rooftop supplies to the primary load DR no.1 (flight simulator unit) via 120 KVA UPS and the primary load DR no.2 (Data Server). Besides, the excessive load will automatically return into the grid and feeding the electrical energy to the rest of secondary DR, and b) when off-grid condition and blackout/brownout condition, similar to the previous algorithm except the 800 kW diesel generators shall operate automatically when the efficiency of PV rooftop is below 43% of total performance.

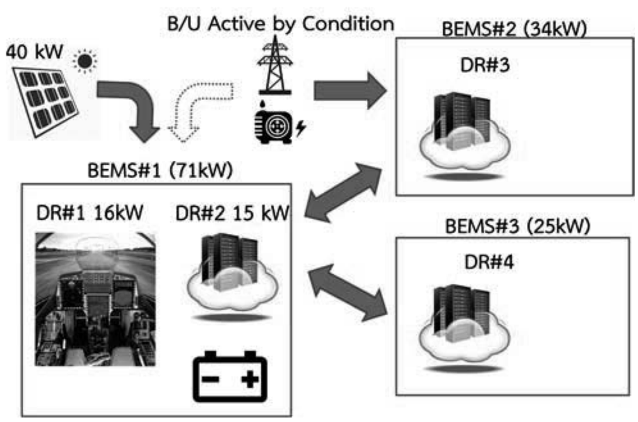

Fig. 1 The Demand Side Management of the Nanogrid supports for the flight simulator system

5.3 The Simulation of DSM Efficiency Forecasting by The HOMER Pro® Microgrid Software

5.3.1 The HOMER Pro® Microgrid Software Benefit

The HOMER Pro® Microgrid Software [20] is the global standard for optimizing microgrid design in all sectors, from village power and island utilities for grid-connected campuses and military bases. The core benefit of the HOMER software is the simulation model, which is able to simulate a viable system for all possible combinations of the equipment that you wish to consider, depending on how you set up your problem.

The detailed design of HOMER Pro® Microgrid Software is shown in Figure 2. The DC input is 40 kW Solar PV Rooftop and is connected via DC-to-AC inverter. The additional AC inputs are the substation grid transmission line and the 800 kW diesel gas generator consecutively. The load profiles are composed with the DR#1 16 kW Flight Simulator Schedule with office hours from 8 am to 12 pm and 1 pm to 4 pm from Monday to Friday, which consumes 83 kWh/day, and the DR#2 15 kW Data Server Schedule with 24/7 operation which consumes 360 kWh/day. The backup 800 kW diesel gas generator shall turn on automatically when there is a blackout or a brownout or when the PV output value is below 43%. The optimization algorithm of DR#1 and DR#2 options are

1) Off-Grid first,

2) If unable to maintain option 1, the algorithm shall select the power from the grid, and

3) If unable to maintain options 1 or 2, the algorithm shall select the power from the 800 kW diesel generator.

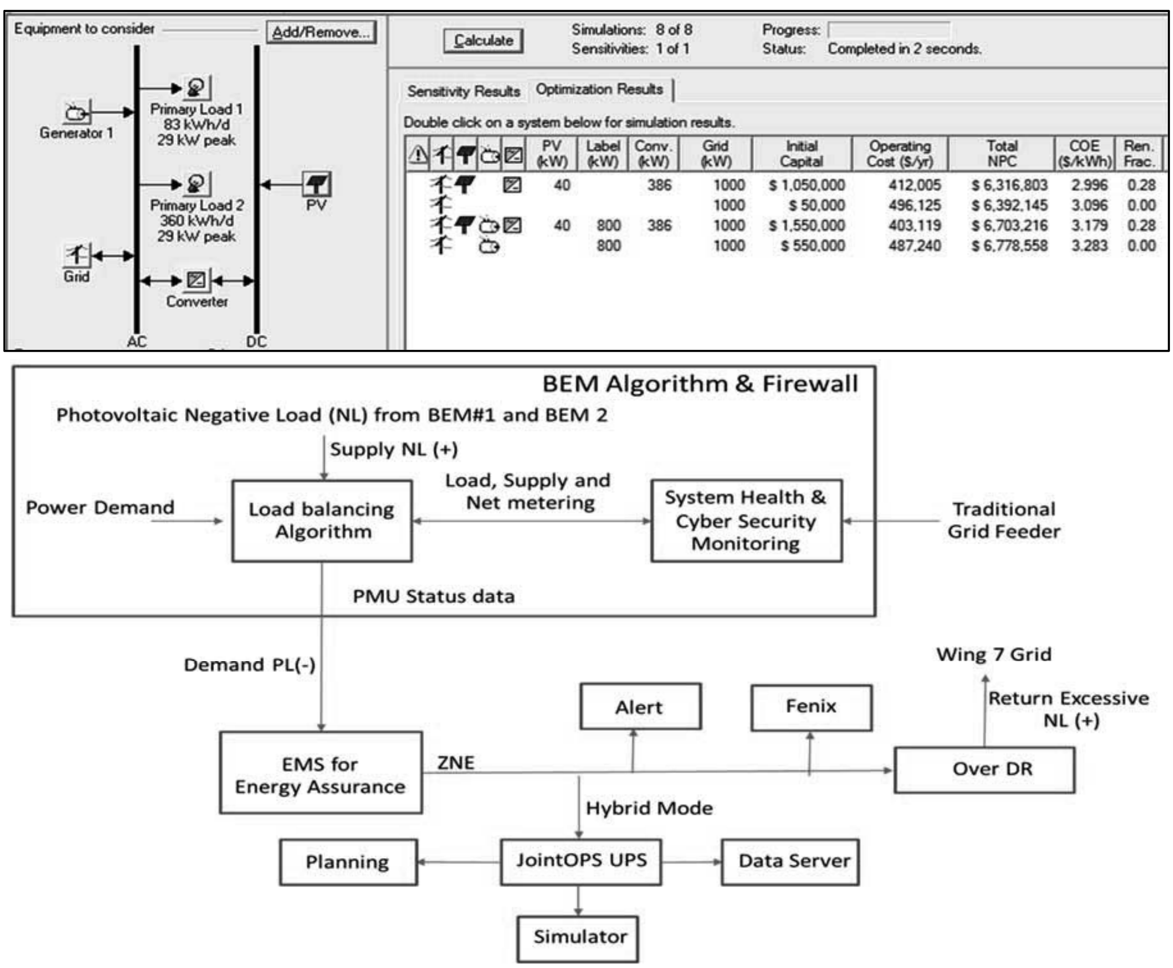

Fig. 2 The schematic and algorithm of hybrid islanded microgrid stability from the HOMER@Microgrid software

5.3.2 The conceptual of Demand Side Management (DSM) Simulation

Firstly, managing the Demand Response (DR) with optimization which matrix in the Schematic of Hybrid Islanded Microgrid stability is made from The HOMER Pro® Microgrid Software is shown in Figure 2. The overall conceptual algorithm is designed based on the input–process–output (IPO) model [21], which automated thinking likes the way the computer thinks.

Secondly, reminding the limitations of DSM Simulation are suitable for a low voltage microgrid design and small- scale power network topology, and not complex. The modeled systems and simulation run are limited with the flexibility options of conventional power Distribution Automation (DA) units.

Lastly, establishing the network community of Building Energy Management System (BEMS) is shown in Figure 3. The Algorithm is based on the peer-to-peer connecting that is one design of major Distribution Automation System Architectures [22]. The benefits of peer-to-peer are, better decision making, more efficiency, handling more event, and the ability to handle a wider variety of events. On the other hand, the disadvantage of peer-to-peer are its requirements for some communication, higher costs, and higher complexity level.

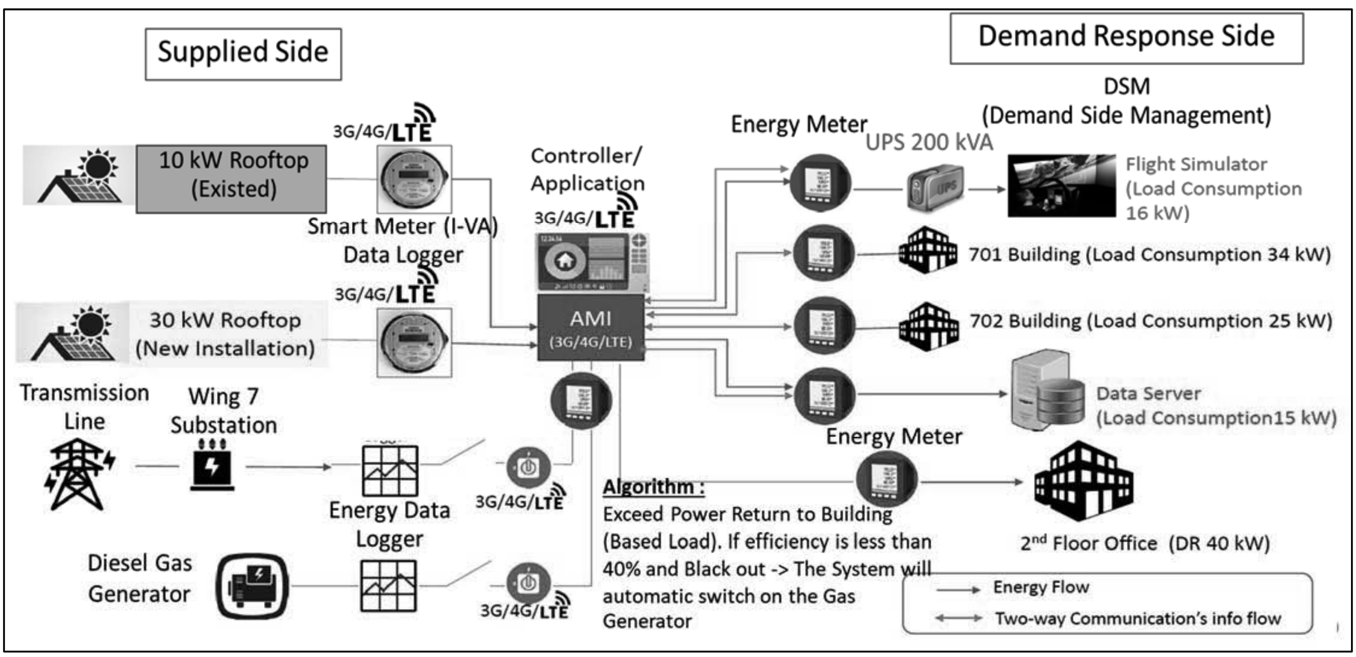

Fig. 3 The network topology of the active energy management system of flight simulator building

Before installing the additional 30 kW PV Rooftop, the existing 800 kW diesel generator has just supplied the electrical power to the building with no specific demand side management. In fact, the 800 kW power production is over supply when comparing to the total load of the actual demand response is required only 387 kW. The researcher redesigns the flow of electrical transmission by initiating from the first priority 387 kW load of five operational buildings as in Table 1. (1. The 71 kW of Flight Simulator Building, 2. The 34 kW of 701 Building, 3. The 25 kW of 702 Building, 4. The 193 kW of 701 Maintenance Hangar, and 5. The 64 kW of 702 Maintenance Hangar). The rest of the 410 kW negative load will be shared to the next lower priority DRs in the vicinity, including the aircraft revetment, the airfield terminal, the support and service office, and the weather forecast office.

The DSM concept is set the 43% of PV output value as the command signal to standby the 800 kW backup diesel generator and readiness for backup the electrical power into the system with some gap of 30-second lag time of fully diesel generator operation. The first prioritized DR is DR#1 16 kW Flight Simulator Unit. The maximum of Solar PV Rooftop is 40 kW, so the 43% of 40 kW is 17.2 kW, the gap between PV output below the DR#1 Load is 1.2 kW (17.2 kW - 16 kW = 1.2 kW). Hence, the researcher set this value as the alert trigger point to automatically send the operational command signal to turn on the 800 kW diesel generator automatically.

5.3.3 Constraints

The limitations of the active energy management system network are: 1) unability to service for 24/7 due to no storage installation, 2) Low sun irradiation when it is raining, cloudy or with low GHI (Global Horizontal Irradiation) situation. The system switches automatically from off-grid mode into an on-grid mode when total of energy performance factor is below 48% of the maximum efficiency of 40 kWh from PV AC-DC Distributed Generation (DG) [23]; the value is from simulator DR is required 16 kWh, that is divided by 40 kWh PV outputs with 0.8 efficiencies, and then multiplying with a 20% safety factor. Furthermore, the additional design is implemented with the fighter pilot's decision making theory named the "OODA loop" (Observe-Oriented-Decision-Action) and the automatic redundant of fly-by-wire [24] system in the modern fighter aircraft. As its smart flight control computer shall respond to monitor, manage, and reconfigure the aircraft stability automatically whatever any worst condition. From US Army War College (2012) [25], The Cyber security is a very concerned issue. It was found that 46 percent of the electricity sector respondents noticed the hidden cyber threats inside their computer systems.

6. Result and Discussion of Efficient Forecast

6.1 Scenario Inputs

The logical algorithm of HOMER@Microgrid software will output the efficient result of the Demand Side Management (DSM) by identifying the best optimization with the least operational cost. The critical combined scenarios are input into DSM are: 1) Off-grid with the economic factor in 2013, the DR of the southern region of Thailand keeps rising on demand continuously. The wide-scale power outage was happened in 2013 [26]. A massive power blackout damaged the 14 southern provinces' cause of a transmission failure by cutting off supplies from the central region. The urgent healing cost of importing the energy from Malaysia was a very high rate-charged that was raised up to 12 Million Thai Baht (Approximately 343,116 $) per 200 MW supply [27]. The average unplanned outage cost of 825 industries in term of peak demand and energy not supplied is 68.47 Baht/kWp and 308.41 Baht/kWh, while the average planned outage cost is 16.23 Baht/kWp and 74.94 Baht/kWh [28], 2) The Data Source of the scaled annual average is 38.5 °C. The value is calculated from the Statistics of temperature at meteorology station, Surat Thani province from 12 years records (2003-2015) [29] as in Table 2. The monthly average temperature and the min/max ambient temperature. The secondary statistic data were referred to as the website accuweater.com [30]. The sets of ambient temperature data are used for calculating the power produced by the PV array, and 3) Blackout/Brownout occurred, and PVOUT is less than 48% of efficiency, then the 800 kW diesel generators shall handover automatically with the average of the diesel fuel price is 1 US dollar per liter.

Table 2 The Statistics of temperature at meteorology station, Surat Thani province: 2003-2015 (12 years records)

Item	2546 (2003)	2547 (2004)	2548 (2005)	2549 (2006)	2550 (2007)	2551 (2008)	2552 (2009)	2553 (2010)	2554 (2011)	2555 (2012)	2556 (2013)	2557 (2014)	2558 (2015)
Surat Thani Meteorology Station													
Extreme maximum temperature	-	-	-	-	38.3	38.1	37.0	39.8	36.5	37.3	39.5	38.2	38.5
Extreme minimum temperature	-	-	-	-	18.3	19.0	18.4	19.5	19.0	20.2	19.0	15.5	18.3
Surat Thani Airport Meteorology Station													
Extreme maximum temperature	37.1	37.5	38.2	36.3	-	-	-	-	-	-	-	-	-
Extreme minimum temperature	19.2	18.5	18.7	18.3	-	-	-	-	-	-	-	-	-
Ko Samui Meteorology Station													
Extreme maximum temperature	36.0	35.8	35.4	35.5	35.3	34.8	35.8	36.3	35.3	36.7	36.2	36.8	36.6
Extreme minimum temperature	20.3	21.9	19.4	20.0	19.5	20.7	20.7	21.5	20.7	22.4	21.5	17.8	19.6
Phra Sang Meteorology Station													
Extreme maximum temperature	38.0	38.0	38.6	37.0	36.8	36.8	37.0	38.3	36.0	36.5	38.6	39.3	39.0
Extreme minimum temperature	19.4	18.3	18.5	16.8	14.4	18.0	16.3	19.0	18.0	20.5	18.8	15.2	17.0

Source : Meteorological Department, Ministry of Information and Communication Technology

6.2 Results of Simulation

According to simulation analysis at the Surat Thani Airport, the monthly PVOUT reports of the baseline data monthly averages and the extraterrestrial horizontal radiation monthly averages are shown in Table 3. In reference to Table 3, the simulated solution has the significant uncontrolled factor that will impact the systematic reliability during November to October (The peak period of the monsoon season). For the demand side management (DSM) of flight simulator, the total of primary demand response is 31 kWh (DR#1 16 kW + DR#2 15 kW = 31 kW = 77.5% from maximum PVOUT 40 kW). The PVOUT productions of baseline data monthly averages from November to October are 0.71966 and 0.71518 (kW/m2), which are lower than the mean of baseline is 0.78375 (kW/m2). Based on this data analysis, there is the possibility to turn on the backup 800 kW diesel gas generators for assisting the PV system when blackout or off-grid happens.

Table 3 The Efficiency forecast output from the optimize model simulation in 2018

Month	Baseline data Monthly Averages (kW/m^2)			Extraterrestrial Horizontal Radiation Monthly Averages (kW/m^2)		
	Minimum Daily low	Average	Maximum Daily high	Minimum Daily low	Average	Maximum Daily high
Jan	0.20371	0.76168	1.11764	0.37489	1.21688	1.24928
Feb	0.23946	0.88106	1.11890	0.40200	1.28660	1.31972
Mar	0.25100	0.90959	1.13502	0.42770	1.34475	1.35776
Apr	0.23808	0.86600	1.08688	0.43761	1.34980	1.35789
May	0.21167	0.74103	1.08953	0.43194	1.31134	1.33335
Jun	0.20792	0.75446	1.07706	0.42490	1.28107	1.28996
Jul	0.20842	0.77481	1.10496	0.42657	1.29109	1.30755
Aug	0.20850	0.76598	1.12720	0.43255	1.32641	1.33988
Sep	0.20713	0.76562	1.15085	0.42868	1.33693	1.34164
Oct	0.20054	0.74997	1.06731	0.40763	1.29218	1.32287
Nov	0.18638	0.71966	1.14027	0.37963	1.22260	1.25462
Dec	0.18867	0.71518	1.00543	0.36469	1.18740	1.19486
Annual	0.21243	0.78375	1.15085	0.41158	1.28725	1.35789

Besides, as shown in Figure 4, the primary demand response load profile (energy consumption) in January is the most critical month. The DR load profile is higher than that of other months because the flight simulator schedules are in operation more than other months to support the pilots upgrade period (Full operating 8 hours per office day). The consequence is the higher usage of two 120,000 BTU air conditioner consumption for cooling the flight simulator system, which was related to the simulated humidity and temperature factor. Conversely, the reasons for the usage of load profiles from February to December in 2018 are due to the lower usage rate of the flight simulator based on annual flying syllabus (Operating 4 to 6 hours per office day). If a blackout or a brownout event occurs in January 2018, the result of the DSM efficient forecast said it is impossible to maintain an islanded condition. Therefore, to maintain the energy assurance and damage prevention for the flight simulator system, the algorithm is necessary to turn on the backup mode of diesel gas generator to support the DSM.

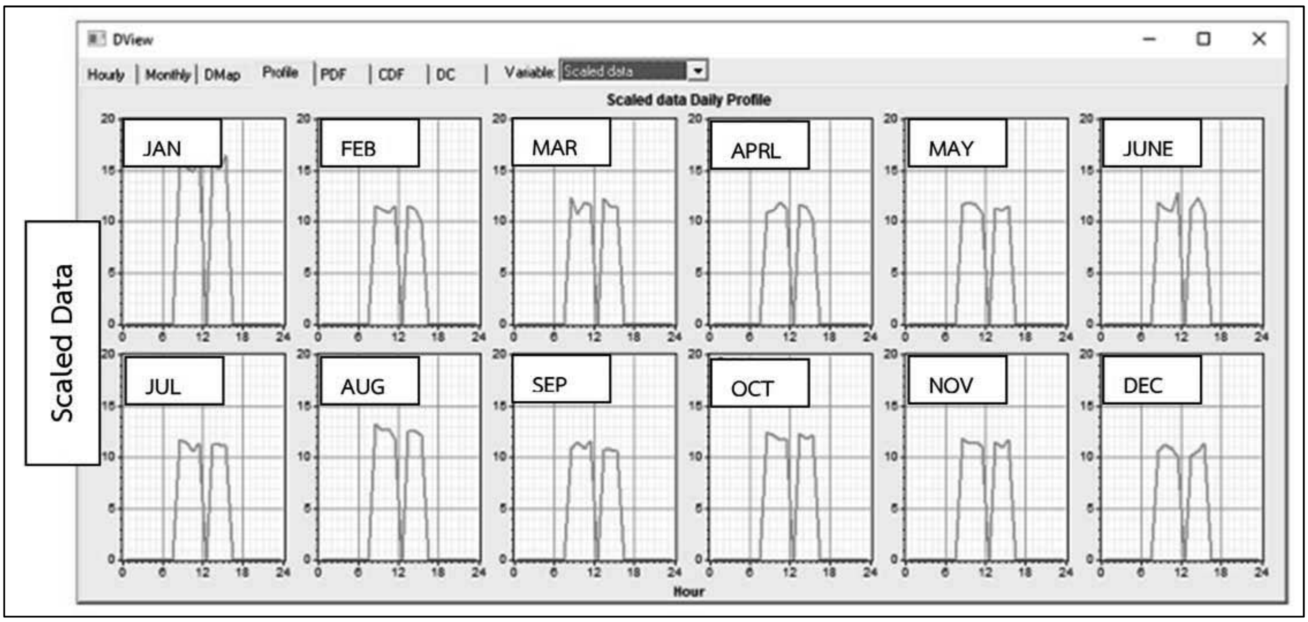

Fig. 4 The primary demand response load profile (Scaled Data Profile) in 2018

The assumption is the low average monthly efficient forecast of output baseline (less than 0.80 kW/m2) in January and between May to December, which is more related to the cloudy condition and humidity and is less related to monthly horizontal extraterrestrial radiation directly even if that has high value. For example, from June to September, the horizontal extraterrestrial radiation has a high value but the monthly efficient forecast of output baseline is low due to cloudy conditions. Subsequently, the solar microgrid produces lower energy and is unable to supply the primary load with islanded mode.

7. Conclusion and Recommendation

The conclusion of the DSM-efficient forecast study is to be able to partially concrete more energy reliability to assure energy and protect the flight simulator from the blackout/brownout damage by installing the islanded Nanogrid model, defining the load prioritization, connecting DSM into BEMS network, and executing software simulation, then analyze and evaluate. This methodology is interoperated along with the RTAF renewable strategy and cyber security policy. The result of simulation, finding the possibility of risk that makes the islanded mode may be degraded from November to January. The two main reasons are:

1) During monsoon season, the GHI received low radiation that caused low of the PVOUT Productivity as well. Because it was the uncontrollable factor by nature, the researcher recommends installing more PV panels on nearby buildings and/or installing energy storage in the future to solve the problem.

2) Gradually, in January, the high load profile consumed a lot of electrical energy caused by the controllable and uncontrollable factors. Firstly, the controllable factor is the high rate of flight simulator scheduling. The researcher recommends solving this trouble by rescheduling some of the non-priority flight simulator activities are shifted after January. Secondly, the weather condition was dry, low humidity and high temperature, and a high consumption of 120,000 BTU air conditioners are the uncontrollable factors. As a result of climate change, the climate in Surat Thani in January is dry, low humidity, and high temperature. The characteristic of Solar Photovoltaic prefers the relative contribution if the high solar irradiance (SI), low ambient temperature (AT), and high relative humidity (RH) [31].

This study's recommendation can apply to sustain the information in the company server or the hospital business. The costs of data or equipment are high-value assets than microgrid and energy management investment. Even though the researcher recommends the energy assurance program, microgrid is unable to fully maintain the islanded mode condition without a diesel gas generator. Especially, the southern area of Thailand has very low GHI radiation during the rainy season. That affects the performance of Solar PV energy production directly. For further implementation, the researcher plans to study the DSM algorithm when installing the Energy Storage System (ESS), including the energy-conservative program for a sustainable organization.

However, this research does not cover all dimensions of DSM conquerable. The recommendation for the next researcher is to investigate the other challenge of EMS approval, which are Integrating communications, Advance components, Improve interfaces, and Advanced Controlling.

8. Acknowledgements

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9. References

(1) DBS Group Research-Equity, "Thailand Power Industry," Asian Insights SparX, Printed 26 April 2017, (Online). Available: https://www.dbs.com/aics/pdfController.page?pdfpath=/content/article/pdf/AIO/042017/170426_insights_neutral_on_thai_power_sector.pdf.

(2) EGAT (Electricity Generating Authority of Thailand), Gross Energy Generation and Purchase (by Type of Fuel), 2017, (Online). Available: https://www.egat.co.th/en/information/statisticaldata?view=article&id=78:gross-energy-generation-and-purchasestatistical&catid= 15.

(3) Chris Bread, Logica, "Smart grids for Dummies-Logica Limited Edition," John Wiley & Sons, Ltd. England. Printed 2010, (Online). Available: https://www.smartgrid.gov/files/Smart_Gridsfor_Dummies_201005.pdf, p. 37.

(4) Royal Thai Air Force (RTAF), "Smart Community project with smart grid enable," RTAF Energy Strategy plan 2010-2025, (Online). Available: https://www.rtafaltenergy.com/attachments/view/?attach_id=142241, p. 28.

(5) Royal Thai Air Force (RTAF), "Smart Grid Seminar. RTAF Renewable Energy News," 2018, (Online). Available: https://www.rtafaltenergy.com.

(6) Corrie Poland, Air Force Energy, "Air Force Energy supports sustainable microgrid project," (Online). Available:https://www.ang.af.mil/Media/ArticleDisplay/Article/2062656/air-force-energy-supports-sustainable-microgrid-project/.

(7) B. Buchholz, Dr., Global Product Manager Microgrids & Distributed Generation, ABB, "Briefing: Affordable renewable microgrids for robust power supply Experiences and trends," PowerPoint., pp. 11-17, 21, 32, 2016.

(8) A. Parida, "A cost effective trade-off based renewable power augmented energy efficient load model for manufacturing industries for demand side management," Cogent Engineering, 2016 (Online). Available: https://doi.org/10.1080/23311916.2016.1239299.

(9) A. O. Rousis, "Design of a Hybrid AC/DC Microgrid Using HOMER Pro: Case Study on an Islanded Residential Application," 5.2 Discussion on the HOMER Pro Optimisation Platform. Licensee MDPI, Basel, Switzerland., 2018.

(10) U.S. Department of Energy, "Demand Response," 2018, (Online). Available: https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid/demand-response.

(11) Chris Bread, Logica, "Smart grids for Dummies-Logica Limited Edition," John Wiley & Sons, Ltd. England, 2010, (Online). Available: https://www.smartgrid.gov/files/Smart_Grids for_Dummies_201005.pdf, pp. 50, 2010.

(12) Homer Energy, "Homer Pro: Efficiency Advance," 2018, (Online). Available: https://www.homerenergy.com/products/pro/docs/3.11/efficiency_advanced.html.

(13) K. Inewski, "Smart Grid Infrastructure & Networking. Chapter 1: Demand-Side Energy Management," The McGraw-Hill Companies, Inc., ISBN 978-0-07-178774-1, pp. 7-10, 2013.

(14) Wing 7 Royal Thai Air Force Base, 2016, (Online). Available: http://wing7.rtaf.mi.th.

(15) NREL: National Renewable Energy Laboratory, Glossary of Solar Radiation Resource Terms, "GHI: Global Horizon Irradiation," 2017, (Online). Available: http://rredc.nrel.gov/solar/glossary/gloss_g.html.

(16) SOLAGIS, "Global Horizon Irradiation (GHI) map," 2013, (Online). Available: http://solargis.com/products/maps-and-gis-data/free/download/asia

(17) Netherlands Embassy of Bangkok, "Solar power in Thailand: Factsheet solar power of Thailand," 2016, (Online). Available: https://www.rvo.nl/sites/default/files/2017/03/FA CTSHEET-SOLAR-POWER-IN-THAILAND.pdf, pp. 1-2, 2016.

(18) FAA (The Federal Aviation Administration), "Technical Guidance for Evaluating Selected Solar Technologies on Airports," pp. 37-40, 2013.

(19) H. Clifford, C. Ghanbari, R. Diver, "Hazard Analysis of Glint and Glare from Concentrating Solar Power Plants," SolarPACES. Berlin Germany, Sandia National Laboratories, 2009.

(20) HOMER Energy LLC, "The HOMERฏ Microgrid Software," 2016, (Online). Available: https://www.homerenergy.com/products/pro/index.html.

(21) Wikipedia, "IPO (input-process-output) Model," 2016, (Online). Available: https://en.wikipedia.org/wiki/IPO_model.

(22) K. Iniewski, "Chapter 2 The modernization of Distribution Automation featuring intelligent FDIR and Volt-Var optimization: DA Systems Architecture and Commu-

nication," Smart grid: infrastructure & networking, The McGraw-Hill Companies, Inc., ISBN 978-0-07-178774-1, pp. 23 -24, 2013.

(23) S. M. Amin, A. M. Giacomoni, 2012. "Smart Grid—Safe, Secure, Self-Healing," IEEE power and energy magazine, 2012, (Online). Available: http://magazine.ieee-pes.org/january-february-2012/smart-grid-safe-secure-self-healing/.

(24) G. Creech, "Digital Fly By Wire: Aircraft Flight Control Comes of Age," NASA Dryden Flight Research Center. 2003, (Online). Available: http://www.nasa.gov/vision/earth/improvingflight/fly_by_wire.html.

(25) B. L. Magnuson, Colonel., United States Marine Corps, "DoD Installation Energy Security: Evolving to a Smart Grid," Strategy Research Project, United States Army War College Class of 2012, Carlisle Barracks, Pennsyvania, 2012, (Online). Available: http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA 561398, pp.14.

(26) T. Fredrickson, Bangkok post: South power restored after Thailand's "worst-ever" blackout (updated), 2013, (Online). Available: http://www.bangkokpost.com/learning/learning-news/351298/south-power-restored-after-thailand-s-worst-ever-blackout.

(27) Minister of Ministry of Energy, "Interviewing: The blackout case in south path of Thailand," 2013

(28) P. Teansri, R. Bhasaputra, W. Pattaraprakorn, P. Bhasaputra, "Outage Cost of Industries in Thailand by Considering Thailand Standard Industrial Classification," 3.6 The outage cost evaluation. GMSARN International Journal 4, pp. 44, 2010.

(29) Meteorological Department, Ministry of Information and Communication Technology, The Statistics of temperature at meteorology station, surat thami province: 2003-2015, 2017, (Online). Available: http://service.nso.go.th/nso/web/statseries/statseries27.html.

(30) Accuweather, "The record of Surat thani province's temperature," 2017, (Online). Available: https://www.accuweather.com/th/th/thailand-weather.

(31) H. Zainuddiin, M. Ismail, N. H. Ahmad Bostamam, M. M. Muhamad Hanifah, M.Z.Hussin, M.F.M Taib, "Ambient Factors Influencing Photovoltaic Module Temperature in Klang Valley," ASEAN Smart Grid Congress 2. Faculty of Applied Sciences, Universiti Teknologi MARA, Shah Alam, Selangor, Malyasia, 2016, (Online). Available: https://fsg.uitm.edu.my/v2/images/images/stories/asgc2/18_asgc2_muhamad_mukhzani.pdf.