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Article

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International Journal of Energy Economics and Policy

Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Lin, Faa-Jeng/Chen, Yenhaw et. al. (2019). Layout strategy of innovative smart grid system integration technology development in Taiwan. In: International Journal of Energy Economics and Policy 9 (3), S. 420 - 425.
http://econjournals.com/index.php/ijeep/article/download/7484/4988.
doi:10.32479/ijeep.7484.

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2019, 9(3), 420-425.

Layout Strategy of Innovative Smart Grid System Integration Technology Development in Taiwan

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Received: 23 December 2018 **Accepted:** 02 March 2019 **DOI:** https://doi.org/10.32479/ijeep.7484

ABSTRACT

Taiwan government has promoted a policy of "Nuclear-free homeland" and increasing the proportion of green energy by 2025, it is expected that Taiwan will experience major energy and social transition. With the vigorous development of distributed renewable energy, Taiwan's energy system will develop towards a multi-energy coexistence, distributed, and regionalized system. In the future, energy systems must integrate various types of power resources, be user-centered, and use information and communication technologies to integrate renewable energy, energy storage systems (ESS), smart meters and other devices. With optimal energy management, energy systems could improve energy conservation efficiency and reduce peak loads, and build a smart green energy system in a more efficient way. Refers to international experience in development trends of distributed power generation, demand response management, ESS and smart energy integration, this study develops and proposes the Layout Strategy of Innovative Smart Grid System Integration Technology Development in Taiwan.

Keywords: Smart Grid, Innovative Integration Technology, Smart Energy
JEL Classifications: L94, O31, Q42, Q48

1. INTRODUCTION

The world has been developed centralized power systems for over 100 years, the overall dispatch and deployment of power systems was all focused on large-scale centralized power plants, and Taiwan is no exception. While the world is actively implementing carbon reduction policies, and the cost of renewable energy such as solar photovoltaic and wind energy is decreasing, global energy transition is underway. However, the expansion of the use of renewable energy will face new issues such as the integration of renewable energy and conventional power systems, operational flexibility and stability of power systems, efficiency of energy business, and market structure.

Taiwan government has promoted a policy of "Nuclear-free homeland" and increasing the proportion of green energy by 2025, it is expected that Taiwan will experience major energy and social transition. With the vigorous development of distributed renewable energy, Taiwan's energy system will develop towards a multi-energy coexistence, distributed, and regionalized system. In the future, energy systems must integrate various types of power resources, be user-centered, and use information and communication technologies to integrate renewable energy, energy storage systems (ESS), smart meters and other devices. With optimal energy management, energy systems could improve energy conservation efficiency and reduce peak loads, and build a smart green energy system in a more efficient way.

Refers to international experience in development trends of distributed power generation, demand response management, ESS and smart energy integration, this study develops and proposes the Layout Strategy of Innovative Smart Grid System Integration Technology Development in Taiwan for reference.

2. TRADITIONAL CENTRALIZED POWER SYSTEM AND ANCILLARY SERVICE OPERATION

Power supply is achieved by electricity generation and delivery, it needs to be able to meet al. consumer demands simultaneously, instantaneously, and reliably (FERC, 2015). To provide users with the power necessary, operation of the power system needs to be planned in advance, and must be guided by this goal. However, with the lack of storage and responsiveness equipment, operators need to plan and operate power plants and transmission grids so that supply and demand can precisely match at all times and destinations. Traditionally, electric utilities have provided services for large regions and developed economic-grade power generation technologies. Nevertheless, the disadvantage of the ever-increasing scale of the generator is that if the unit is unexpectedly shut down, it is immensely difficult to replace. In order to solve the problem of high reserved capacity cost of centralized power systems, the power company has built a backup capacity on the bilateral interconnected transmission lines sufficient for transmission of power between neighboring power companies so as to transmit power in the event of major accidents in the power generation equipment. Therefore, traditional ancillary services are more focused on maintaining the reliability of electricity and supporting transmission systems that are generated and consumed immediately within a short period of time.

3. RENEWABLE ENERGY FEEDING INTO GRID AND DEMAND SIDE MANAGEMENT DEVELOPMENT TREND

3.1. Renewable Energy Feeding into Grid Issues and Corresponding Mechanisms

Wind power, solar photovoltaic and other renewable energy sources possess unstable power supply characteristics. Traditionally, the voltage on the power line gradually decreases with load current from the substation to the end of the line, but as the solar photovoltaic power generation system gradually feeds in, the voltage on the line may rise due to the reverse power of the distributed power supply, which cause the terminal voltage to rise. The margin of power system frequency will also increase, affecting the stability of the power grid. In recent years, there have been restrictions on the use of intermittent power generation due to the power grid's ability of adopting those capacities.

Renewable energy has become one of the main power sources in the power system and has accumulated a great deal of operating experience in the world due to past measures such as Feed-in Tariff, preferentially feeding into power grid, or the requirement of the electric utilities to bear the burden of renewable energy allocation. The voluntary market is expected to further increase the proportion of renewable energy in the power system on account of the significant reduction in the cost of generating renewable energy such as onshore wind power and solar photovoltaics and the importance of corporate social responsibility in expanding the use of renewable electricity in recent years. The mechanism of intermittent renewable energy power generation feeding into the power grid will also be converted from privileged priority grid connection in the past to strengthening the management of renewable energy into power grids or strengthening the forecast of renewable energy power generation, and will require renewable energy power generation equipment to participate in the scheduling and dispatching mechanism of the power system operation.

3.2. Demand Response and Virtual Power Plant Concept

Demand response is the dynamic adjustment of electricity consumption after coordination with the power system or electricity market conditions. The design of the demand response plan is to facilitate and coordinate power usage in response to power system needs. From the power grid operator's point of view, demand response is to achieve net reduction/increase of power supply from the grid through the application of multiple types of demand response resource, so that distributed power generation, load dispatch, energy storage, or other resources that generate a net change in the amount of power supply to the grid can achieve the best efficiency of energy use through the energy management system (EMS).

Virtual power plant integrates users, such as residential, commercial or industrial users, under different electricity pricing systems, demand response programs, or distributed power generation equipment schemes (Yenhaw et al., 2013). According to local distribution grid type and its geographic location in combination with user-end technologies, including distributed and renewable energy power generation, energy storage management systems, demand response, and power management systems, etc., the operational decision software developed by local operators and the advanced communication technologies were applied to perform immediate power monitoring and coordination. The concept of virtual power plant can be viewed as another power plant that can be operated and dispatched by power generation utilities and electric utility vertically. Electric utilities can use standard attributes such as maximum/minimum capacity and power rise/drop to optimize their overall operational portfolio in response to changes in load and power generation. For distribution utilities or electricity retailers, virtual power plants can also be used to change the overall business model. Electricity retailers can also use various forms of virtual power plants to reduce reliance on independent power dispatch centers/electricity trading markets, even participate in independent power system operation or electricity trading market bidding as an Aggregator.

4. INTERNATIONAL SMART ENERGY INTEGRATION DEVELOPMENT STATUS

4.1. The Impact of Development on Digitization of Energy System

Digitization transforms energy system essentially and continuously, as in other related industries, the change has now occurred in traditional energy and related industries, affecting the corresponding new market players such as private, public and industrial users. Digitization is developing at an impressive rate in almost all areas of life, this phenomenon is also occuring in the energy system. Since Taiwan opened up the energy market and decided to head for energy transition, digitization is an important turning point in future development and will deeply affect all stakeholders in the energy system. Modern enterprise management applies multiple methods developed by digital technology to ensure the smooth development of its business in a constantly changing market environment. From the perspective of policy options, these diversified approaches to digital science and technology will help to effectively and efficiently achieve the goals of energy transition.

Significant and dynamic market changes will come along with the digitization development, in this regard, either the enterprise's own business strategy or regulatory framework policy will need to be adjusted. In other fields (e.g., retailer), the essential feature of digitization is to drastically change the established business role and innovation value chain in the form of Disaggregation or Aggregation, that is, to dismantle and re-architect traditional business models. This feature will also impact the traditional power economy, as the network becomes digitized, the establishment of digital platform and novel business model will expand the mutual influnece between separate industries and make them more complex. In this way, an innovative network will gradually formed.

Digital technologies such as digitized network measurement, control, and adjustment technology, big data, cloud computing, learning systems, and artificial intelligence could bring new and far-reaching possibilities to technological solutions and technical units in its value creation processes, or to basic optimization of collaborative operations between market stakeholders and users, etc., especially to the coordinated operation of the energy system.

Digitization can bring opportunities for the society and some users to realize the potential of achieving economical energy elasticity and efficiency that cannot be achieved so far. The realization then can have a dynamic impact on the energy service market (dena, 2016). Taiwan's advantages in distributed energy system technology and digital technology will enable it to properly manage the new requirements and social impacts of energy transition.

4.2. International Smart Energy Integration Application Development Trend

The energy transition of introducing large-scale renewable energy into traditional power systems will face the challenges of integrating renewable energy with traditional power systems (Yenhaw et al., 2017), operating the power system with flexibility, maintaining the stability of the power system, improving energy efficiency, and establishing the structure of smart energy system and its market.

To this end, Germany promotes the Digitization of the energy transition project (Digitale, 2016). It combines smart grid technology, information and communication technology, demand management and other ancillary services to enhance the added value of energy transition. It also converts large amount of green power from solar and wind energy into safe and efficient base-load power, and applies with innovative grid technology and management concepts to promote regional energy system transition. Japan is strengthening its energy supply structure by establishing a multi-layer supply system to leverage its energy supply advantages. It will establish EMS, correspond to distributed energy systems and storage facilities, through advanced demand management methods by 2020. This could integrate and activate energy supply and demand, making distributed energy systems and storage facilities into virtual power plants.

Countries are looking forward to strengthening demand-side management, renewable energy, energy storage, and smart grid applications by applying digital technology solutions to establish regional smart energy management and supply systems.

5. LAYOUT STRATEGY OF INNOVATIVE SMART GRID SYSTEM INTEGRATION TECHNOLOGY DEVELOPMENT IN TAIWAN

5.1. The Necessity of Taiwan to Promote the Development of Smart Energy Integration

The government in Taiwan is pushing a nuclear-free homeland policy by 2025, including measures to increase the proportion of green energy generation. It is expected that Taiwan will experience major energy and social transition process. The energy utilization and renewable energy of various regions in Taiwan have their own characteristics. For example, the northern Taiwan is the major energy demand region, its peak load demand relies on electricity generated in the south of Taiwan, and thus demand management will be its core. The central region has offshore and onshore wind power resources. In the southern region, solar photovoltaic installations account for >70% of those in the country, and can be integrated with ESS to become virtual power plants (Faa-Jeng et al., 2015).

The legislative Yuan passed the amendment to the electricity act to add renewable energy in electric power supply and renewable-energy-based electricity retailing enterprise to the electricity industry. The concept of virtual power plant allows distributed power supply and demand response in each region to be combined with aggregator business model (Yenhaw et al., 2016). In collocation with the amended law, these micro capacity owners can participate in the electricity market through new mechanisms in the law. This will make good use of local resources to expand green energy use, improve energy efficiency, increase the willingness of people to save electricity, reduce the risk of power shortage, and establish a standard for future regional energy use planning.

5.2. Smart Energy Supports Taiwan's Power System Development Opportunities

Traditional power system operation focuses on the reliability and economic dispatch of the power system. For instance, power system owners could enhance transmission infrastructure to share nearby resources, or power system operators could choose spare capacity or lower cost generator to reduce the operation cost. With the decreasing cost of renewable energy and energy storage technology, distributed power has become one of the mainstream power sources for future power systems. The digitization development of the power system can strengthen the application of smart grid and promote smart energy integration. By integrating the value chain of traditional power system and distributed power sources, renewable energy, ESS and demand management can be incorporated to enhance power system reliability and economically dispatch available resources.

All new Taiwan power company plans regarding grid revolves around the new "multi-energy coexistence, distributed and regionalized energy grid" concept. Faced with the large number of renewable energy sources, the future power grid must integrate various energy types and modes of operation, be user-centered, and use information communication technology to integrate new equipment such as: ESS, smart meter, power quality control and carbon capture technology, in order to promote energy conservation, reduce peak load, and build a more efficient low-carbon green energy grid. The strategy adopted includes (1) constructing a localized distributed power grid, expanding the grid-connected capacity of renewable energy; (2) combining smart technologies and planning regional power grids; and (3) integrating power generation resources and appropriately deploying power (Taiwan Power Company, 2016).

With the trend of global renewable energy development, in addition to strengthening the power infrastructure such as renewable energy, smart meters, and power grids, Taiwan's power system development needs to focus on the use of various regional resources to integrate and link traditional power mechanisms, and strengthen the role of power dispatch service centers at all levels. Power dispatch service centers will act as a co-operating platform of power distribution system, user-side renewable energy system, and ESS, adjust demand resources with flexibility to enhance system reliability and sustainability.

5.3. Recommendations on the Layout Strategy of Innovative Smart Grid System Integration Technology Development in Taiwan

Taiwan Power Company's power dispatching is a three-level pyramid model. The top is the Central Dispatch and Control System (CDCS). It adopts dual-master and mutual backup modes, and is responsible for the whole system's power dispatching. The middle is the Area Dispatch and Control System (ADCS), and the bottom is the Distribution Dispatch and Control System (DDCS). The Taiwan Power Company's CDCS has an EMS, and each ADCS also has its own EMS. At present, the DDCS does not have an exclusive EMS, it uses the EMS of the ADCS (Taiwan Power Company, 2015).

In the face of energy transition challenges, in addition to renewable energy power generation technology upgrades, infrastructure expansion and demand side management and other ancillary services, the innovation of infrastructure is also required. The integration of innovative technology or ancillary services with consumers and existing energy infrastructure will open up innovative or even disruptive business models to provide consumers with more incentives to choose from the market, driving consumers and energy developers to move toward the goal of expanding renewable energy use.

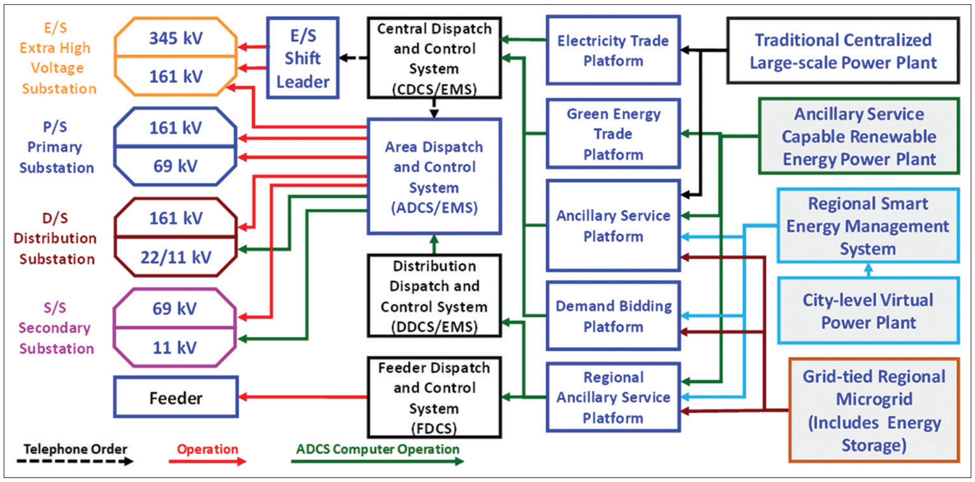
To achieve goals of: (1) ensure the safety and efficiency of grid operation in the case of high proportion of renewable energy; (2) explore more potential for efficiency and application flexibility improvement in the electricity market and grid; (3) ensure participants in the smart energy systems can cooperate safely and efficiently; (4) use existing grid architecture more efficiently; (5) reduce the expansion of distribution power grid, achieve the goal of national energy transition, it is suggested to develop integration technologies and platforms that are connected to Taiwan Power Company's dispatch and control systems in Taiwan (Faa-Jeng et al., 2017), as shown in Figure 1.

"Medium and large-scale ancillary service capable renewable energy power plant" is based on active and reactive power control and advanced inverter technology, it develops medium and large-scale renewable energy power plants as related functions of power grid ancillary services. It can be used to smooth renewable energy power generation with ESS and provide emergency rapid discharge capability and optimal charging and discharging strategies to maintain power quality and power supply stability. In addition to promote sustainable development and connectivity of green energy, it ensures stable energy supply and overall economic stability.

With the peak load reduction of industrial users is approaching saturation and smart meter deployment is increasing, small demand of the metropolitan area to participate in the demand response can expand the demand source and stabilize the power supply in the metropolitan area. "City-level virtual power plant" in conjunction with the liberalization of the electricity market can attract users to participate in the power business by introducing demand response technology, renewable energy power generation equipment, energy storage equipment, fuel cells and other distributed power generation equipment. Local governments construct a dedicated EMS as Aggregator to gradually promote the small demand to participate in demand response and expand the adjustable demand in the metropolitan area, so as to make up for the capacity gap after stable reduction of nuclear power in the future, and drive the emerging green energy and power industry.

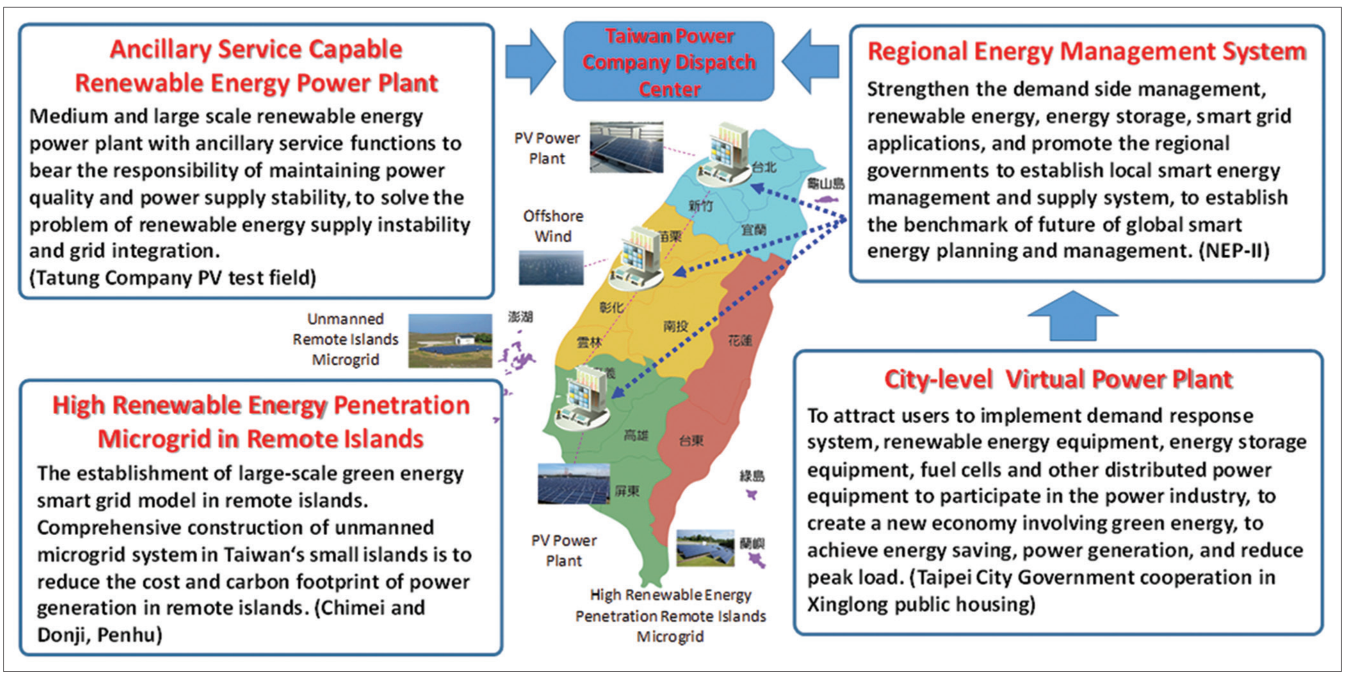
"High renewable energy penetration smart grid/microgrid in remote islands" is to develop smart grid and microgird technologies to achieve high penetration of green energy in Taiwan's large-scale remote islands. By planning suitable solar photovoltaic system, ESS and smart grid EMS to cooperate with existing diesel generators, renewable energy penetration will be increased significantly and make green energy fully utilized. This can reduce the cost of power generation and improve power quality on the remote islands, thus establishes a cost-effective composition ratio of solar photovoltaic, wind power, energy storage, and diesel generator capacity to establish a model of promoting the construction of high penetration of green energy smart grid on remote islands. Taiwan's small-scale remote islands

Figure 1: Future high renewable energy penetration power dispatch framework concept of Taiwan



Source: Taiwan Power Company, NEP-II

Figure 2: High renewable energy penetration smart grid development vision (Resource: TIER)

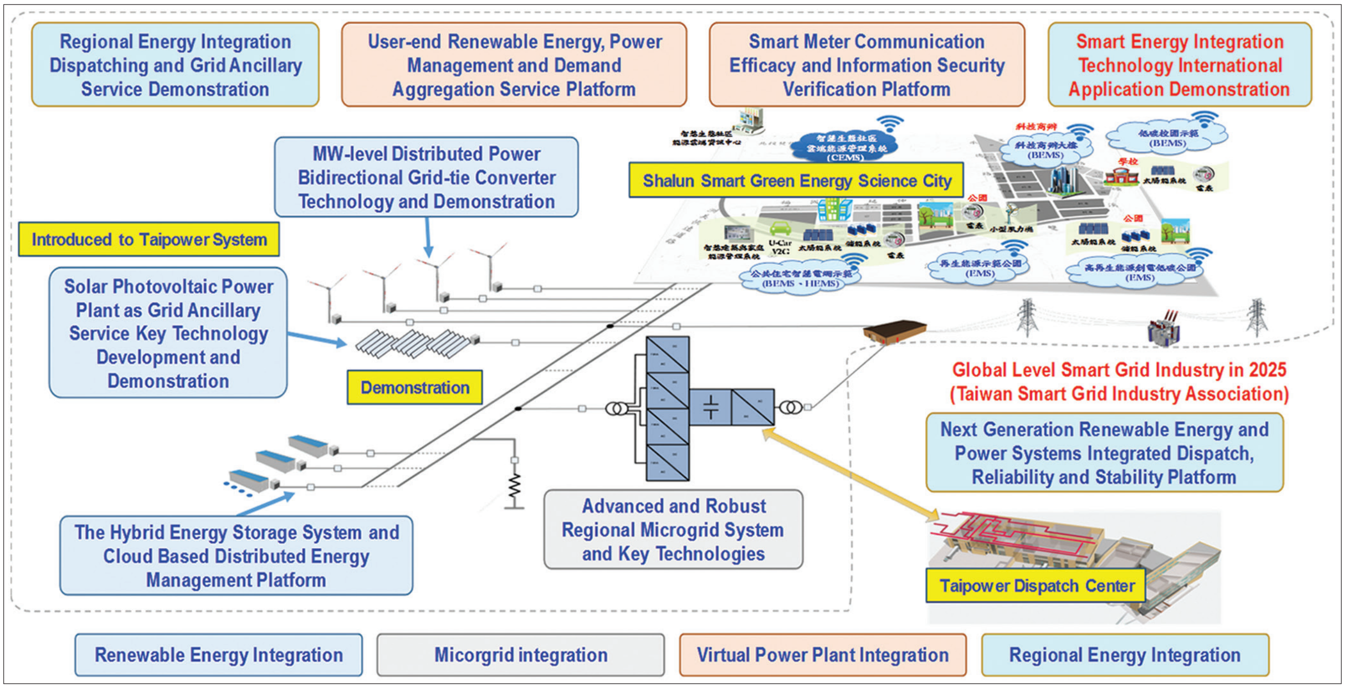


then can use the power generation forecasting, load forecasting and remote monitoring functions of the microgrid EMS to fully build an unmanned microgrid system.

Energy utilization and renewable energy in various regions of Taiwan have its own characteristics. For example, the northern part is the major energy demand region, the central part has offshore and onshore wind power resources, the southern solar photovoltaic resources are abundant, and the east is rich in geothermal and marine energy. Smart grid technology and virtual power plant business model can be used as a driving force for Taiwan's smart energy integration and construction of a green energy supply system. In line with the opening of the future power industry, all county and city governments can set up regional smart energy management centers to promote the "Regional Smart EMS", strengthen demand-side management, renewable energy, energy storage, and smart grid applications in the region. The county and city governments together with Taiwan power company, can establish regional smart energy management and supply systems, as shown in Figure 2.

While expanding the use of renewable energy, it will face new issues in the integration of renewable energy and traditional power systems, system operation flexibility, system stability, energy efficiency and market structure. It is recommended that the project can be linked to Shalun Smart Green Energy Science City (SGESC). Strengthening the layout of innovative system integration technologies, such as "The Hybrid ESS and cloud based distributed energy management platform", "user-end renewable energy, power management and demand aggregation service platform", "solar photovoltaic power plant as grid ancillary service key technology development and demonstration", "regional energy integration dispatching and grid ancillary service demonstration", "advanced and robust regional microgrid system and key technologies", "MW-level distributed power bidirectional grid-tie converter Technology

Figure 3: The proposal of innovative system integration technology of Shalun smart green energy science City (Resource: TIER)



and demonstration", "next generation renewable energy and power systems integrated dispatch, reliability and stability platform", "smart meter communication efficacy and information security verification platform", and "Smart energy integration technology international application demonstration" to promote technical practicability and economy required for energy transition.

In addition to the aforementioned innovative system integration technology development, Taiwan also needs to apply these advanced technologies in the power system for distribution utilities' needs in specific regions, such as congestion management, maintenance of power quality, reliability, and economic operation, in order to promote distributed power supply into the electricity market, and help to comprehensively improve the renewable energy penetration level of the power system (Figure 3).

6. CONCLUSION

SGESC plans to introduce applications of energy conservation, energy creation, energy storage and system integration, and seeks the integration of industry, academia and research institutes to systematically integrate and develop green energy technology solutions. In terms of system integration, it is recommended to promote the development of energy integration technology using smart grid technology, and combine the traditional energy field with the new green energy industry value chain, ensuring stable supply of energy and optimizing the overall economy.

It is also recommended to use innovative market mechanisms and seamless digitization to promote the demonstration of large-scale green energy society, taking technology and system support, regulatory environment, business model and social interaction as a core and using grid, market, data processing technology and digitization interaction to create opportunities for new business models of energy transition to promote regional energy integration and achieve national energy transition goals.

REFERENCES

Deutsche Energie-Agentur GmbH (dena). (2016), Grundsatz Papier der Plattform Digitale Energiewelt.

Digitale Agenda für die Energiewende and EWE. (2016), Verbund Projekt Enera.

Federal Energy Regulatory Commission. (FERC) (2015), Energy Primer a Handbook of Energy Market Basics. Washington, DC. Federal Energy Regulatory Commission.

Taiwan Power Company. (2015), Power System Load and Dispatching [PowerPoint Slides]. Taipei, Taiwan: Taiwan Power Company.

System Planning Division, Taiwan Power Company. (2016), New thinking on the planning of green energy and low carbon power grid. Taipower Journal, 644, 26-29.

Faa-Jeng, L., Yenhaw, C. (2017), Innovative System Integration Technology Development-Blueprint for Layout and Application of Smart Grid from 2017 to 2026. R and D Department of Green Energy Industry Promotion Center.

Faa-Jeng, L., Yenhaw, C., Su-Ying, L., Yvonne, H. (2015), The smart grid technology development strategy of Taiwan. Electromechanical On-Site Technical Bimonthly, 81, 108-119.

Yenhaw, C., Chang, P.N., Liu, C.H., Lu, S.Y., Tso, C., Chi, G.C. (2017), Strategy of using regional energy integration technology to promote energy transition in Taiwan. Taiwan Economic Research Monthly, 40(5), 22-28.

Yenhaw, C., Su-Ying, L., Yang, H.T. (2016), Study on the promotion method of smart grid integration in smart cities. Taiwan Economic Research Monthly, 39(4), 108-119.

Yenhaw, C., Su-Ying, L., Faa-Jeng, L. (2013), Introduction to virtual power plant concept and operation mode. Power Electronics, 11(4), 46-53.