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Review Article

Prospects and Challenges of Malaysia's Distributed Energy Resources in Business Models Towards Zero – Carbon Emission and Energy Security

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Abstract. For a decade, distributed energy resources in Malaysia have growth as one of the paths in battling with sustainable energy crisis and environmental pollution. Several intriguing initiatives and incentives have been established to encourage the use and sales-side of renewable energy at the distribution consumers. However, Malaysia's distributed energy resources penetration is still at its slow pace, with only 7.6% (excluding large hydropower) shared in energy mix generation. Therefore, innovation in power systems is required to drive the uptake of distributed energy resources. This paper reviews the business model innovation that allows distributed energy resources to participate in national grid services and the wholesale electricity market. Different technical and non-technical challenges with high shares of variable renewable energy in power systems are highlighted, and the current update on compensation scheme, Net-Energy-Metering 3.0 is also discussed. Along with these challenges, stance the prospect of adopting distributed energy resources innovation projects such as peer-to-peer energy trading and virtual power plant in the electricity market. It could further furnish the benefits to a better environmental and power system in terms of carbon dioxide avoidance, grid flexibility and increase revenue for distributed energy resources owners respectively. Through the review, it led to observation that policy and regulatory in Malaysia are the main factors in accelerating the distributed energy resources deployment. Therefore, the abilities and roles of Malaysia Energy Commission and Sustainable Energy Development Authority as a regulator and implementing agencies are crucial in determining the present and future distributed energy resources business model.

Keywords: Distributed energy resources; Zero-emission; Energy security; Peer-to-peer energy trading; Virtual power plant

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Introduction

The global energy demand is envisaged to increase 30% by 2040 (IEA, 2019d). Simultaneously, it will cause an extreme pressure on energy sources and environmental issues. Hence, the sustainable and clean energy exploration is crucial to cater with the expanding population and rapid revolution in economic growth. For that reason, many countries such as China, U.S.A. and Europe have started committing with low-carbon technology by welcoming renewables into their energy mix (IRENA, 2021). Distributed energy resources (DER) are one of the examples that apply low-carbon technology which able to mitigate climate change impacts and improve energy security. DER is known as a small-scale power generation (i.e., solar PV, biogas, biomass, small hydro) directly connected to the distribution network. DER can be further versatile by adding other components such as energy storage systems (ESS), electrical vehicles (EVs) and demand-side measurement (Dahlan *et al.* 2022).

A country's energy security is generally defined as the continuous availability of energy supply at affordable prices (IEA, 2019a). Malaysia is known as one of Southeast Asia's biggest countries and economics, thus making energy security the utmost influential agenda. (Foo, 2015) and (Sahid *et al.* 2013) underlined that over-dependency on fossil fuels and imported energy are the main threatening issues of energy security in Malaysia that can affect the country's future development. Therefore, through the DER system, abundant renewable energy (RE) could be harnessed effectively thus eliminating energy security

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risks. For instance, by using ESS as behind-the-meter business models, the consumers can store the electricity produced by solar PV rooftop and use it later, when needed, or sell it back by injecting to the grid. Furthermore, DER can also provide the best alternative modern energy services solution while enabling active players in a decentralized energy ecosystem.

DERs are being increasingly deployed globally. For example, the massive installation of small-scale solar PV in Australia is expected to meet the energy demand of about 30% to 45 % by 2050 (Australian Energy Council, 2020). Similarly, countries like China, U.S.A. and European Union are aggressively focusing on small-scale renewable energy together with enormous usage of electric vehicles (EV) and demand response for their DER elements (IRENA, 2019). It has become urgently necessary to address the DER operation to ensure it can provide the optimum results economically and efficiently in this market context. (Li, 2017) had examined the financial gains ratios for three (3) distributed solar PV business models, i.e., grid buyout, self-consumption, and feedback into the grid after self-consumption. It also covered the in-depth advantages of distributed generation projects for various investor entities. The other authors identified that the present DER business models are more influenced by governmental and regulatory rather than technological factors, which will substantially change the future business models (Burger & Luke, 2017).

Malaysia had started embracing DER through Renewable Energy Act 2011 especially for solar PV adoption. Programmes like Feed-In-Tariff (FIT), several series of Net-Energy-Metering (NEM), solar leasing and solar Power Purchase Agreement (PPA) have been established as a business concept to further boost the RE deployment at the distribution sides (Husain *et al.* 2021). The initiatives able to save consumer electricity bills, reduce carbon dioxide (CO_2) emissions and lessen the energy security risks by having a backup renewables supply (Oh *et al.* 2018a). A progressive roadmap is needed to spur the Malaysian DER energy market further. Hereof, in 2019 the government conveyed a clear message through Malaysia Renewable Energy Roadmap (MyRER) by setting up a new target for RE integration to 40% by 2035 (SEDA, 2021). Four (4) technology–specific pillars (i.e., solar, hydro, bioenergy and new solution/resources) have been identified under MyRER to fulfil the RE capacity goal and have a low carbon energy system. The roadmap seems significant in enabling this country's DER business models such as peer-to-peer energy trading (P2P) and virtual power plant (VPP).

The liberalization of global energy markets has created prospects for DER market-oriented operations. Previous studies on DER in Malaysia have yet to discuss the prospect of P2P energy trading and VPP business models in detail. Therefore, this research assists to fill the knowledge gap by reviewing Malaysian DER landscape from the liberalized market perspective toward an environmental concern and energy security. As for the beginning, the works highlight the current RE status in Malaysia notably for solar PV that explains various projects installed capacity and initiatives offered for users. The paper also explains and compares each policy on RE compensation schemes in chronological order until the recent release policy, NEM 3.0. Correspondingly, the paper states technical and non-technical challenges that need to be tackled in DER environment. Finally, the works reviews the ongoing DER business model in Malaysia, such as P2P energy trading and VPP in the view of investment in power system infrastructure.

2. Malaysia Renewables Energy Sector

Malaysia is a developing country with a highly robust industrialized market with an increasing Gross Domestic Product (GDP) yearly. In 2019, the Malaysian GDP was worth RM 1526.63 (USD 364.70) billion. The growth of GDP describes the socio-economic development, which relies on any country's long-term energy security. Apparently, due to the retiring of fossils fuels sources, technological advancement and falling prices for solar PV, the RE sector is flourishing at its fastest pace globally. Therefore, these opportunities will eventually facilitate the growth of sustainable RE projects in Malaysia. Since National Renewable Energy Policy and Action Plan (NREPAP) was introduced in 2011, this country has been committed to having sustainable and security energy.

However, since the COVID-19 outbreak at the end of 2019, the pandemic has severely impacted global economic activities. As reported by (International Energy Agency(IEA), 2019), about 15% decline in electricity demand would be experienced by countries that strictly implemented Movement Control Order (MCO). In Malaysia, the economic impact due to COVID-19 was visible mainly contributed by energy demand decaying which was about 5% during the first ten (10) months of 2020 (IEA, 2020). However, despite the pandemic eruption, solar PV remains a significant source to steer the alternative RE capacity in this country. The government has created several initiatives to boost RE development after this pandemic. Regardless of economic contraction due to COVID-19 fallout, the government launched a 1 GW fourth large-scale solar (LSS) farm project as an economic recovery plan (Yurnaidi & Rosalia, 2020). The project can be the upturn of the Malaysian economy sector as it is expected to spur job creation and increase solar capacity availability.

Further initiatives to boost RE sector during the post-pandemic were seen in the revised NEM 3.0 from the previous NEM 2.0 by adding more 500 MW allocation for solar PV rooftop installation quota. One of the schemes under NEM 3.0 is the concept of Virtual Net Energy Metering (VNM), known as Net off Set Aggregation (NOVA), which has been brought to present the new bill crediting system within the solar community. As part of stakeholders in RE sector in Malaysia, the educational sectors are encouraged to participate in solar PV deployment through green campus projects. Universiti Teknologi MARA (UiTM) for instance is committed to reducing its CO_2 footprint by investing in RE projects with a long-term plan. UiTM is the first higher learning institution in Malaysia that owned and operated its LSS project in Gambang (50 MW), Pahang and Pasir Gudang (25MW), Johor. As of to date, seven (7) UiTM campuses nationwide have been installed with solar PV rooftops that are capable of supplying 11.057 MW capacity to the grid, which is equivalent to 74,000 tonnes per annum reduction in carbon footprint (see Figure 1) (UiTM Holding, 2020). UiTM is further committed to installing more solar PV rooftops at all 35 campuses nationwide to become a carbon-neutral university and achieve its energy conservation consumption plan. Despite the uncertain future of the COVID-19 crisis, it can be an impetus to relook at the electricity industry to promote national energy security with long-term efficiency.

To accelerate the DER adoption, the Supply Agreement with Renewable Energy (SARE) contract is offering for solar PV rooftop installation with zero upfront payment (i.e., solar leasing and solar Power Purchase Agreement (PPA)) (The New Strait Times, 2019). SARE is a programme that undertakes all aspects related to agreements and policies of supplying and consuming RE in Malaysia. SARE involved a tripartite contract between prosumer, investor, and Tenaga Nasional Berhad (TNB) to protect all parties' interests. Table 1 shows the details of this tripartite agreement between TNB (billing agent and utility owner), solar investor, and building owner (for billings and invoicing matter). Solar leasing programme in Malaysia is eligible for residential, commercial and industrial sector. It's allowed the prosumers to take advantages on the environmental benefits of solar system without owning the system. This programme is similar to renting whereby the prosumers must pay the monthly fixed amount for the system to the leasing company and can use the electricity generated from the solar PV system. The leasing company is entitled for a tax rebates, tax breaks and financial incentives such as Green Investment Tax Allowance (GITA), Green Income Tax Exemption (GITE) and Green Technology Financing Scheme (GTFS).

Fig. 1 UiTM campuses with solar PV rooftop under NEM 2.0

Table 1
The characteristics of solar PPA, solar leasing and solar hybrid via SARE contract

Component	Solar Leasing	Solar PPA	Solar Hybrid
Upfront cost	Free	Free	Range 20%
System owner	Investor	Investor	Investor
Contract duration	3-10 years	21-25 years	21-25 years
Instalment	Monthly fixed	Based on kW generated monthly	Monthly fixed + kW generated monthly
Deployment Sector	Residential/ Commercial/ Industrial	Commercial/ Industrial	Commercial/ Industrial
Carbon Credits	Investor/ owner	Investor/ owner	Investor/ owner

Source: (TNBX, 2019)

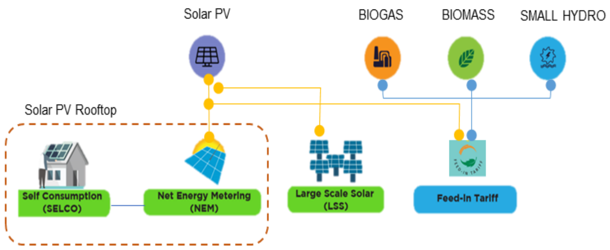

Fig. 2 RE compensation schemes in Malaysia

On the other hand, the concept of solar PPA is almost similar to solar leasing except for a lengthy contract duration, deployment sector and monthly installment payment. During the contract term, consumers are required to pay for solar energy generated by the system at the current solar rate. Normally, companies that do not intend to own the assets of solar panel or benefits for tax rebate will choose for solar PPA. While solar leasing and PPA required no upfront cost, the solar hybrid required at least 20% of the total overall cost. The system is more expensive than the other two since it comes with an energy storage system. Under solar hybrid contract, the consumers will get the opportunities for monthly bill saving since they can use or trade the generated solar PV and stored energy based on their time of use.

2.1 Renewable Energy Compensation Schemes

As a step towards restructuring the Malaysian electricity grid landscape, the RE compensation schemes have been revised from time to time since 2011 to value the environmental benefits. Starting with FIT adoption, the compensation schemes are then revised to NEM, self-consumption (SELCO), NEM 2.0, e-bidding FIT and the recent NEM 3.0. Figure 2 shows the current RE compensation scheme programmes offered in Malaysia. NEM and SELCO scheme is purposely developed for solar PV rooftop prosumers, while the current version of e-bidding FIT is only eligible for biomass, biogas and small hydro project sectors. Before NEM was introduced, solar PV installed are entitle for FIT scheme. The LSS projects are based on competitive bidding programme among the project developers. With various of compensation schemes available in this country, it will lead to high-intensity integration of DER and subsequently change the energy market trading arrangement. The structured compensation schemes are vital as a regulatory instrument to encourage RE adoption.

2.1.1 Feed-in-Tariff (FIT)

In 2011, Malaysia introduced FIT mechanism following the Renewable Energy Act to encourage more Independent Power Producers (IPP) on a small scale to generate electricity from RE and sell it back to the grid through an incumbent utility company. At that time, FIT rates depended on the types of RE used (i.e., solar PV, small hydro, biomass and biogas), installation capacity, date of commencement, and criteria. The overwhelming demand and growth for FIT had resulted in the falling cost of solar PV systems by 23% between 2011 and 2016 (Oh *et al.* 2018b). Within that period of years, numbers of LSS farms have been successfully built, such as 10.25 MW LSS in Gemas, 4 MW at the rooftop of Kuala Lumpur International Airport (KLIA), 10 MW parking lot solar canopy nearby KLIA2, 8 MW in Ayer Keroh and Pajam and 5 MW in Sepang and Alor Gajah. Under FIT rates, all projects were signed for solar PPA between TNB and solar farms for 21 years.

The Renewable Energy Fund (REF) has been introduced to lessen the government's financial burden on FIT mechanism. The primary purpose of REF is to promote the growth of RES in electricity generation. The electricity surcharge at 1.6 % has been imposed on consumers who consume more than 300 kWh of their monthly electricity usage (Tenaga Nasional Berhad (TNB), 2016). The consumers that consume more kWh are the major contributor to REF. Though it seems a burden to consumers, this is one of the progressive steps to encourage RE deployment. Nevertheless, in 2016, the FIT scheme reached its maximum capacity.

Introduced in 2018, a mechanism known as e-bidding FIT (e-FIT) has been implemented to discover the competitive FIT rate between biogas, biomass, and small hydro. The e-FIT is performed through healthy competition among private small-scale RE IPPs. The e-FIT had received favourable response from IPPs whereby Sustainable Energy Development Authority (SEDA) reported that as of June 2019, 12,540 applications had been ratified with 1,744.38 MW of total installed capacity. Small hydropower holds the prevailing share with 34.6% and is followed by solar PV (25.4%), biomass (23.5%), biogas (14.4%) and geothermal (2.1%) (The News Straits Times, 2019). Being an incumbent utility company in Malaysia, TNB holds a significant share in constructing and managing large hydropower plants (>30 MW capacity). Any hydropower project rated below 30 MW is considered a small hydropower plant that will be operated by a private developer. Since Malaysia is the world's largest palm oil producer, therefore, the availability of biomass resources is enormous. By 2023, 189.5 MW additional installed capacity of e-FIT projects will be ready for commission.

2.1.2 Net Energy Metering (NEM)

Poised with the idea of the prosumer, NEM has entered the electricity market in 2016 to replace FIT. The first version of NEM stated that consumers are to self-consume their generated solar PV and sell the excess energy generated at prevailing displaced cost (RM0.31 (USD 0.073) / kWh) to utility. The government allocated a 500 MW quota for NEM scheme from 2016 until 2020 with 100 MW each year capacity limit (90 MW allocation for Peninsular Malaysia and 10 MW for Sabah) (Oh *et al.* 2018b). However, the first NEM scheme did not manage to attract more participation from the small-scale IPP due to the non-attractive financial incentive.

To overcome the drawbacks of NEM's first version, NEM 2.0 was introduced in 2018 and enforced in January 2019. The NEM 2.0 scheme is based on a true net energy metering concept that will benefit residential, commercial, industrial, and agriculture. In November 2020, the allocation of 500 MW capacity for NEM and NEM 2.0 schemes had reached its quota. In December 2020, the government announced revised initiatives for NEM 2.0. Every 1 kWh exported to the electric grid will be offset against 1 kWh imported from the grid through the next month of electricity billing. The ministry stipulates that one-to-one offset rates were only for ten (10) years. The System Marginal Price (SMP) rate tariff structure will be imposed after ten (10) years of solar PV installation. The

NEM 2.0 prosumers can continue saving their electricity bills by joining SELCO after the SMP offset period rate expires (Kementerian Tenaga dan Sumber Asli, 2021).

The government is responsible for enforcing a proactive mechanism to ensure competitive compensating cost on every RE-generated electricity. Therefore, to continue solar PV rooftop installation initiative at commercial buildings and residential premises, the Ministry of Energy and Natural Resources has announced NEM 3.0 programme scheme with another 500 MW quota allocation starting 2021 until 2023. Through this programme, three (3) initiatives have been established to widen the prosumers' opportunities to install solar PV rooftops at their respective buildings for electricity bill saving (refer Table 2). The government had specifically targeted domestic consumers to participate in " NEM Rakyat", government entities in "NEM GoMEn" while NOVA is notably for commercial and industrial energy users. NOVA is a new market approach introduced based on virtual net metering (VNM) that depends on SMP real-time wholesale pricing (Kementerian Tenaga dan Sumber Asli, 2021). The concept of NEM 3.0 is similar to NEM 2.0 whereby any excess power generated is allowed to be rollover within 12 months for NEM GoMEN and NEM Rakyat while one (1) month for NOVA starting from the consumer's first billing system. However, NEM 3.0 rollover mechanism is only valid for the first ten (10) years. After that, participants will be automatically changed to SELCO scheme.

The VNM concept allowed owners of commercial and industrial buildings to share their excess generated solar PV at their respective subsidiary buildings that have constraints installing solar PV rooftops. In general, the netting concept of VNM is applying billing software whereby host solar property can share their net metering credits to participating consumers on a predetermined basis. For instance, as captured in Figure 3, the host solar property export 200 kWh to the grid to be shared with its subsidiary (without solar PV) that consume 1000 kWh for its energy. Through VNM, at the end of month, the subsidiary will be billed only for 800 kWh instead of 1000 kWh used. The same concept has been deployed successfully in several countries globally, like in U.S.A (2008), Australia (2015), Brazil (2015), Greece (2016) and Canada (2017). The deployment of VNM is envisaged to bring cost-effective aggregations in energy pooling and provide a new pathway to encourage consumers to participate in renewable electricity generation.

Table 2
Malaysian NEM 3.0 Mechanism

Subject	NEM *Rakyat*	NEM GoMEn	NOVA
Participants	Domestics Users	Government Buildings	Commercial & Industry Users
Technology	Solar PV rooftop	Solar PV rooftop	Solar PV rooftop
Quota Offered (MW)	100	100	300
Roll Over Mechanism	NEM 1:1 basis for 12 months	NEM 1:1 basis for 12 months	SELCO+1 month
Duration Offer		3 years	
Offset Rate	Current Tariff	Current Tariff	System Marginal Price (SMP)
After 10 Years		SELCO	
Installation Capacity Limit	Single-phase = 4 kW_{ac} Three-phase = 10 kW_{ac}	1 MW_{ac} per 1 account	Net Offset (NO) = 1 MW_{ac} Net Offset Virtual Aggregation (NOVA) = 5 MW_{ac}

Source:(Kementerian Tenaga dan Sumber Asli, 2021)

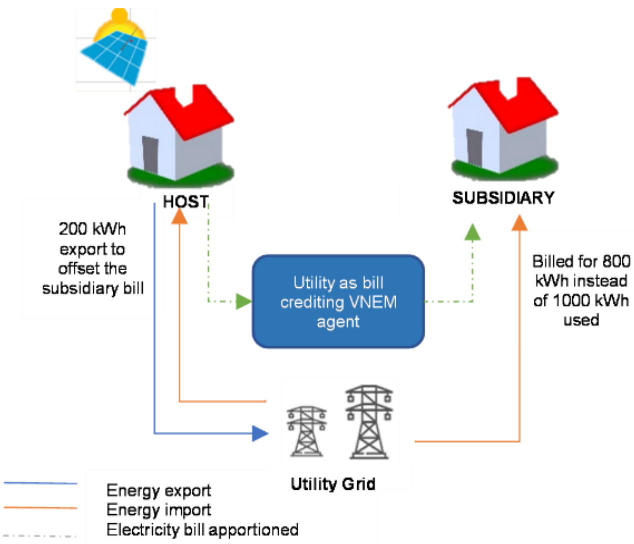

Fig. 3 Overview of VNM concept

2.1.3 Self-Consumption

The technologies of solar PV have become cost-effective and affordable for its adoption. SELCO defines that electricity generated by solar PV must be entirely consumed, and any excess energy generated is not allowed to be exported (SEDA, 2019c). Since 2017, the electricity consumers in Malaysia have been asked to incorporate SELCO to reduce dependency on the grid and offset their electricity bills. The current revision of NEM 2.0 and NEM 3.0 states that after certain years of subscription, the compensation scheme will automatically change to SELCO (Malaysia Energy Commission, 2021). The SELCO consumers can choose between normal flat-rate tariffs, Time-of-Use (TOU) or Enhanced-Time-of-Use (ETOU) tariffs for electricity grid purchasing prices. Integrating ESS with solar PV can further contribute to energy cost savings and security supply for SELCO consumers.

3. Challenges with DER Integration

The integration of renewables at distribution sides as energy diversity will contribute to various technical and retail electricity pricing challenges. More explanation about challenges is detailed in the following subsections.

3.1 Technical Grid Flexibility Interconnection

The interconnection of DER with power grid could offer various benefits such as reducing losses at transmission and distribution levels, improving energy efficiency, diversification of renewables power sources, enhancing system reliability and decarbonizing the energy sector. Extensive studies show that deploying distributed generation with RE integration is more economical than upgrading the distribution and transmission of existing facilities, especially in remote area power supply (Pahle *et al.* 2016; Santos *et al.* 2017; Zerrahn *et al.* 2018). However, it may increase the responsibility of distribution system operator (DSO) to manage supply and demand while ensuring uninterrupted power supply due to changes in load demand pattern and intermittent RE supply. As the largest utility provider in Malaysia, TNB is targeting to experience only one (1) day/year of loss of load expectation (LOLE) event in peninsular Malaysia. The LOLE can be happened due to power deficits between supply and demand that are caused due to uncertainties of load, intermittent behaviour of RE connected at the generation side and power plants outage (Celik, 2007; Zafir *et al.* 2016). DER coupling with the grid may drive several technical impacts such as voltage instability, frequency regulation, power quality, and protection levels. Therefore, technological advancement is required for solutions that comply with grid utility requirements.

3.1.1 Efficient Management in Planning and Scheduling

The integration of RE in the electricity portfolio will disrupt the conventional ways for planning daily operations in the power grid. Efficient management in planning and scheduling of RE at distribution sides is imperative to avoid any undesired variable output that will significantly daunt the power system operation. The tasks are challenging since the generation output for RE is subject to weather variations (i.e., solar irradiance, temperature, and wind speed) and highly diffusion in energy demand response at the distribution level. (Zhang *et al.* 2019) explored an effective heuristic time-scaled weather prediction based on day-ahead and real-time. By using Tabu search, the optimal scheduling of DER can be obtained while reducing the mean average forecast errors. In another study, (Bird *et al.* 2013) stated that a load forecasting method had become a prerequisite in power generation to obtain operational efficiency decisions on the energy demand either day-ahead, hourly, or in another short-term manner. (Nam *et al.* 2020) through its comprehensive study had listed Autoregressive Integrated Moving-Average (ARIMA), Advanced Neural Network (ANN), Kalman Filter method and Multiple Linear Regression (MLR) as the most popular used models for load forecasting.

3.1.2 Supply-Demand Load Balancing

Another challenge encountered with grid connected DER is load balancing between supply and demand. With bi-directional electricity flow and supply intermittency, DSO needs to coordinate closely with the transmission system operator (TSO) to balance the whole system. Henceforth, to support and facilitate the configuration of electricity flow, DSO must expeditiously respond to any power fluctuation to maintain a safe and reliable power grid towards a low-carbon future (Weiss *et al.* 2019). Nowadays, batteries as energy storage have gained more attention due to the rapid decline in their cost (Cole *et al.* 2017). The deployment and management of BESS can reduce energy curtailment, especially during surplus situations in the event of high feed-in RE (Zerrahn *et al.* 2018).

Recently, Malaysia has been planning to install a utility-scale BESS capacity of 500 MW between 2030 and 2034 (Malay Mail, 2021). Figure 4 illustrates the block diagram of PV-battery energy storage system (BESS) grid-connected configuration at the distribution side and its bi-directional power flow. Since the solar PV-BESS is installed before the prosumers' energy meter, the system is often called a behind-the-meter. Generally, the system is suitable for energy arbitrage, self-consumption, demand charge reduction and as a backup electricity supply for grid stability (Mishra *et al.* 2020). Figure 5 depicts the sample of energy trading dispatch with a solar PV – BESS system under ETOU tariff rate for one week in a Malaysian office building. The dispatch algorithm will balance the energy trading and peak shaving to minimize the electricity bill. It was observed that during the lower price of ETOU, the load is mainly met by purchasing the electricity from the grid and a small portion from the BESS until the state of charge (SOC) decreases to its minimum value declared, i.e., 20%. When the solar PV production starts, the load will be powered by grid and solar PV. The grid has purchased zero energy at the highest solar PV production (exceeding load).

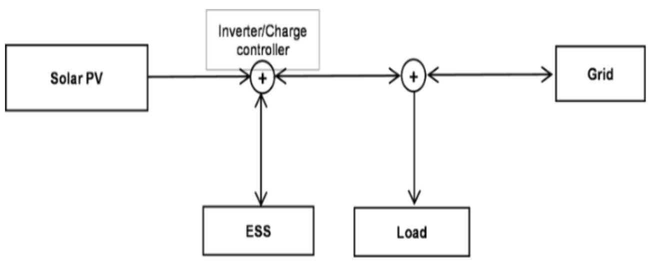

Fig.4 Solar PV-battery grid connected system configuration

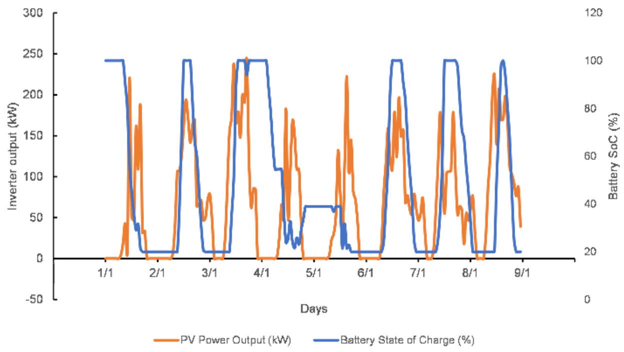

Fig. 5 Energy dispatch for solar PV-BESS under ETOU tariff rate (Ilham *et al.* 2022)

The excess solar PV will charge the BESS until it reaches 100% SOC and the remaining will be exported to grid. As the solar PV production decreases towards the evening, the battery will begin discharging and supply the loads combined with energy supplied from grid. In the event of BESS charging, it can be charged from solar PV and purchased from grid.

The study found by Denholm and Mai's discovered that energy curtailment could significantly reduce the pattern of RE behavior generation at short term and low power (Denholm & Mai, 2019). The deployment of controllable loads such as plug-in hybrid electric vehicles (PHEV) and EV can cause a changing pattern in electricity demand profiles. These vehicles' uncontrollable charging could contribute to the stresses and imbalance in distribution grids (Oldenbroek *et al.* 2021). Therefore, proper coordinated time and ESS types used for PHEVs and EV charging are imperative. It could assist in guaranteeing the load balancing in energy supply-demand with renewables (Ikegami *et al.* 2012).

3.1.3 Grid Synchronization

With grid connected DER, both generation and distribution sides are experiencing variables supply and demand patterns. Prior connecting DER with the power grid, it is essential to ensure that voltage, frequency, and phase sequence are controllable to ensure network harmonisation is adhere the operation system requirement. Hadjidemetriou *et al.* (2013) had modelled a solar PV grid-tied inverter (GTI) to convert the direct current into alternating current to match the voltage and frequency designed by the utility provider. Hereof, numerous methods have been discussed aiming for efficient and rapid grid synchronization that can be applied in single or three phases with further classification in time and frequency domain. A detailed review conducted by Jaalam *et al.* (2016) identified methods such as zero-crossing detection, Kalman filter, discrete Fourier transform, etc., that could detect the frequency, phase, and magnitude by implementing open-loop systems analysis. In the event of updated parameters, a closed-loop systems analysis can accommodate any circumstances. The rapid growth of grid connected DER performance should be further supported through advanced control of the inverter technologies without jeopardizing the effect of coupling with another system such as heating and transport (i.e., PHEV) sectors.

3.1.4 Power Quality Issues

Power quality (PQ) disturbances have become nuisance problems that could severely impact the power grid with RE. The common causes of PQ events are high penetration of RE in electrical profile and increasing usage of power electronics at the load side. In operational and performance aspects, several factors, namely disparity of PV/wind output profiles and the efficiency of converter/inverters, could contribute to voltage mismatch between RE and grid systems. Furthermore, uncontrollable total harmonic distortion (THD) during switching time may malfunction the protection devices, transformers and capacitor bank overheating, and resonances in the grid system (Jaalam *et al.* 2016). Series and parallel harmonic resonances are also exhibited at the interconnection point between inverter impedance and grid, leading to tripping, unbalanced and voltage disturbances (i.e., sag, swell, fluctuation, and interruption).

Likewise, previous research stated that integrated multiple PV units with a distributed network and harmonic interfacing between different inverters were also shared in the inflating of THD (Miveh *et al.* 2015; Trivino-Cabrera *et al.* 2017; Weng *et al.* 2016). For that reason, various PQ mitigation techniques have been proposed that involve compensating devices which include Flexible AC Transmission Systems (FACTS), unified power quality conditioner (UPQC), active filters, passive filters and hybrid filters (Ullah *et al.* 2020). These techniques should preserve the power grid frequency at its permissible limits (i.e., IEE Std.1547, IEEE Std.1588-2008, IEEE Std.929-2000) to refrain from power outages and difficulties in controlling PQ events (Etxegarai *et al.* 2015).

3.1.5 Self-Healing Protection

The main aims of having self-healing protection systems are to ensure the continuity of power supply to the users, fault-tolerant systems, and the ability to have a resilient system under different abnormal conditions with diversified presences distributed generation, ESS, controllable loads and demand response. A bi-directional power flow in DER will significantly change the fault current direction, duration, and magnitude (Ullah *et al.* 2020). Consecutively, coordination and sensitivity limits for protection devices are crucial to adjust their short circuit levels. A rapid voltage recovery system and a responsive communication network are mandatory for any exchange of information during normal and faulty conditions. In these situations, the power grid system should maintain continuous operation and autonomously manage the loads either in interconnection or islanded grid while reclaiming the faults by self-healing strategy (Refaat *et al.* 2018). Artificial intelligence (AI) has been applied to self-healing energy infrastructure systems at different responses as an agent-based intelligent model. Research conducted by (Ferdous *et al.* 2020) found that at least one microgrid should have adequate power to supply the deficiency of other microgrids. The results on self-healing microgrids overload management were observed to be satisfactory among ESS and microgrids.

3.2 Non-Technical Challenges - Fixing the Retail Electricity Price

The high-intensity integration of RE at the distribution side will subsequently change the way electricity is traded in the market. Currently, NEM and FIT mechanisms are the most widely used schemes in RE trading (Do Prado *et al.* 2019). However, those mechanisms are mostly suitable for a small scale of distributed integrated renewable within the residential and commercial. Specifically, since 2011, the RE compensation schemes in Malaysia have changed several times to value the environmental benefits. Currently, the typical payment structure for NEM compensation has been upgraded to a bill crediting system through VNM adoption that will benefit the solar community. As for the future prospect of DER, the government has indicated that solar PV users are expected to self-consumption their renewable energy generated (Kementerian Tenaga dan Sumber Asli, 2021).

This incentive scheme transition showed that all stakeholders, such as regulatory, utility companies, consumers, and DER producers, are now concerned about retail rate design to ensure fair cost recovery and rate-responsive demand (Braithwait, 2018). The cost recovery in this context, referred to as the significant installation of distributed generation may steer to a shortfall in the utility company's revenue due to its reduced electricity sales while bearing with additional investment for a smarter grid. As the load demand and renewable generation vary, the present static retail rates are not responsive to dynamic RE generation changes over time. A reasonable retail electricity price is crucial to be formed by the government and its respective agencies as this may discourage consumers from producing more clean energy since no incentive is offered for their dynamic RE generation.

4. Malaysia's DER Potential Business Model

In 2020, IRENA had identified five (5) potential business models namely (1) VPP/aggregator; (2) P2P energy trading; (3) energy as services; (4) community ownership models; and (5) pay as you go models. Malaysia is currently in the early phase of pursuing P2P energy trading and VPP business models toward a smarter grid in moulding the future electricity sector. These models are expected to lower the carbon footage, provide high capabilities to coordinate demand and supply in the energy network while at the same time offering a sustainable and secure power supply.

4.1 P2P Energy Trading

Due to the high penetration of DER, P2P energy trading is envisaged as the new approach for the future of electricity being traded. Initiated from the P2P economy concept, it is usually implemented within a local distribution system (i.e., region, cell, microgrid and premises) (Mengelkamp *et al.* 2018). P2P energy trading aims to balance energy supply and demand in a real-time, autonomous, and decentralized manner. Prosumers are defined as proactive consumers who will vigorously manage their own generated DER in energy production, self-consumption, storage, and energy trading (Morstyn *et al.* 2018). With the maturity of RE technologies, IEA has forecasted that by 2024, 100 million homes globally will have the solar PV rooftop, giving valuable prospects for P2P energy trading deployment (IEA, 2019b).

SEDA Malaysia introduced P2P energy trading pilot run in November 2019 within a sandbox environment. The main objectives for this eight (8) months pilot project are to address the issues such as 1) determine the regulatory required, assess the technical requirement for P2P energy trading; 2) resolve the financial impact between prosumers and consumers; 3) identify the motivation for participation among stakeholders and 4) addressing the barriers and its mitigation actions concerning the P2P energy trading (SEDA, 2019a). Figure 6 illustrates the P2P energy trading model proposed in Malaysia. The model comprises three (3) leading players: consumers, NEM prosumers, and TNB. In this model, TNB acts as a grid operator that coordinates energy and money exchange trading between prosumers and consumers via the virtual blockchain platform.

A smart meter was installed at the prosumer and consumer sides to record the import and export kWh. The average cost of kWh generated by prosumers is around RM 0.355 (USD 0.085) /kWh, and they are allowed to sell back at RM 0.3905 (USD 0.093) /kWh. An additional grid retailer fee of RM 0.063 (USD 0.015/kWh is proposed to be imposed on the consumer's side when purchasing the electricity from prosumers. The trial project was only eligible for TNB consumers according to Tariff B – Low Voltage Commercial Tariff (RM 0.509 (USD 0.12)) /kWh). Based on theoretical calculation, the prosumers will be able to obtain approximately 11% profit. However, for the purposed of this pilot project, the grid retailer fee was not accounted in the calculation.

This project successfully ended its trial in June 2020 with a better understanding, especially on the P2P energy trading concept, advantages and challenges. Although some of the project's objectives have been constructively achieved, further improvements must be made toward P2P energy trading implementation in Malaysia. Additional studies related to the impact of P2P on the grid, economic feasibility and designing appropriate business models are essential to be conducted before its live deployment. A report by (SEDA, 2019b) claimed that about 4.12 million buildings in peninsular Malaysia have the potential for rooftop solar installation. With the enormous installation prospects, it can generate more electricity at once, thus promising electricity sustainability through P2P energy trading. In realizing the P2P concept, the developed virtual energy trading platform should assist prosumers and consumers in trading their electricity reasonably. Technologies maturity is essential to enable the global P2P energy trading development. These technologies must evolve and mature accordingly to realize the capacity of P2P energy trading in becoming a smarter grid (IqtiyaniIlham *et al.* 2017).

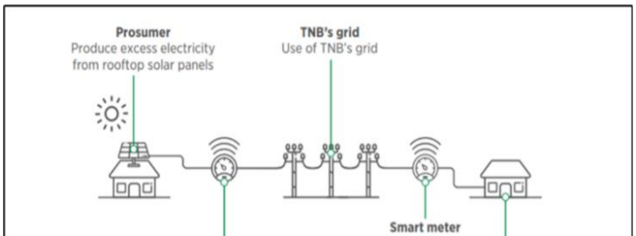

Fig. 6 P2P energy trading model in Malaysia (SEDA, 2019a)

4.2 Virtual Power Plant

VPP appeared as a new decentralized energy generation model in a cloud-based that is able to improve reliability, stability, services, and power losses. The VPP can be defined uniquely depending on the system operator's desired framework, and the concept overview is illustrated in Figure 7. The aggregator is known as a company that operates a VPP by bundling DERs in power system market. Their available intelligent dispatch units and its virtual platform in VPP components enable energy trading in wholesale markets to be performed. VPP also provide local flexibility at the distribution operation level by controlling different types of DER types (i.e., solar PV, wind, ESS, PHEV, etc.) (Saboori, 2017). The Energy Management System (EMS), known as the heart of VPP will coordinate the flow of power from diverse types of generators, storage and controllable loads (Maanavi *et al.* 2019). As many countries in the world have started deploying VPP, the current global market value for VPP has amounted to USD 0.87 billion in 2019 and the number is projected to reach USD 2.85 billion by 2027 (Fortune Business Insights, 2019). Countries like Australia, U.S.A and Europe Union are actively involved in VPP that provides real-time data management, remotely control of DER, energy forecast, scheduling and trading based on day-ahead and intra-day (Energy & Meteo Systems, 2020; Next Kraftwerke, 2020).

Countries in the Asia Pacific are also experiencing the rapid growth of economics that motivated them to strengthen their VPP market to ensure grid security and resilience. Malaysia, for instance, is an exemplary country in this region with enormous opportunities for VPP. In 2019, TNB took the initiative by partnering with a South Korean energy power company to explore the concept of VPP applied at the national grid during peak demand with the presence of RE and BESS. The co-pilot project, which amounted to USD 7 million, covered installing five (5) BESS units. Each BESS with 1 MW capacity installed over the Klang Valley area will be tested for 30 months which could benefit the local grid network (The New Strait Times, 2019). Several vital successes for developing VPP in Malaysia can be listed as high penetration opt for RE, flexibility in regulatory frameworks and attractive incentive schemes. Even though Malaysia has fulfilled the indicators of having huge prospects in VPP, without meaningful incentives and a revised regulatory framework in the energy market, the commercial projects involving VPP will remain a challenge.

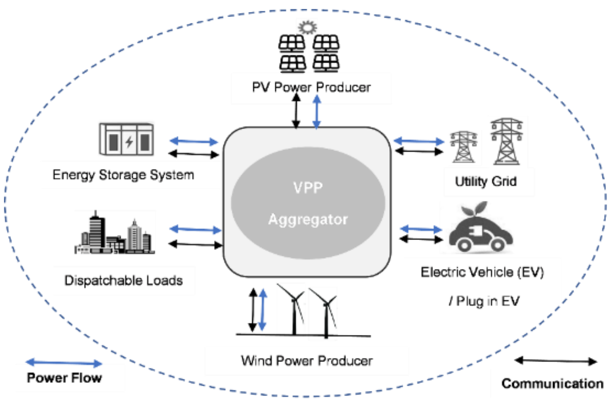

Fig. 7 Overview of Virtual Power Plant

5. Discussion

In this section, the discussion on challenges and prospects of Malaysian business models in DER are grouped into two (2) fields. The first field refers to the challenges and prospects of DER in providing the solutions to drive the uptake of variable renewable energy into power systems. In the previous section on integration challenges and potential of DER business model, it can be seen that the stakeholders involved such as end-users, utility companies and developers required bettering policies and mature technologies that can directly impact the profits, cost – efficiency and system reliability. The P2P energy trading and VPP have been identified as the most potential DER business models in this country, involving huge investment on those projects. Although the P2P pilot test had reached its end, the government has yet to announce a future path despite industrial participants' decisive feedback, especially on the electricity bill savings. When comparing the RE compensation schemes with cash profit and incentives, it was observed that the earlier FIT (2011) successfully fostered solar PV deployment in Malaysia. Nevertheless, this scheme was found unable to be supported in the future due to massive competition and development in RE technologies that required different mechanisms in line with technology changes (Sovacool & Drupady, 2011). Therefore, the government introduced several LSS projects that assimilated the auctions system for electricity price generated and several versions of NEM. The first and second series of NEM had seen only passive solar PV prosumers in energy trading market. However, the recent NEM 3.0 enables commercial prosumers to conduct extreme projects that allow excess solar PV generated to be shared with other subsidiary buildings using the VNM concept and the integration of BESS in grid-connected solar PV. As this country is still struggling to find ways to benefit all stakeholders, the government and the policymakers should investigate the value of BESS as a behind-the-meter element under different tariffs and compensation schemes to determine which programme the prosumers are better off.

Meanwhile, the second field refers to DER challenges and prospects for Malaysia's zero-carbon emission and energy security. In this context, the integration of RE is an exemplary option that can provide a prompt impact on reducing GHG emissions while assuring energy security enhancement. BESS usage can improve energy security by its flexibility to ramp up and down the sudden power surge from intermittent RES like solar. Although this country is recognized for its abundant natural energy resources, some limitations on the inconsistent financial support, policy innovation, unattractive compensation schemes and tariffs may hinder the expansion of RE usage at the distribution side. Since 2011, the country has yet to revise the RE Act which aimed to increase RE's install capacity in energy generation. As the country has been pressured to decelerate its GHG emissions level, the RE Act and its relevant policies must be revised and innovated. Apart from solar PPA, leasing and LSS projects introduced, initiatives such as tax exemption for RE owners, BESS and energy-efficient vehicles (EEVs) adoption could be the prudent path. Furthermore, Malaysia should consider implementing a carbon tax as a critical tool for every tonne (s) of carbon emission toward achieving a 1.5°C climate target as pledged in the Conference of Parties (COP) 21 – Paris Agreement. The revenue obtained from the carbon tax mechanism can be used for further decarbonization action plans. The awareness campaigns need to be regularly conducted to educate the public about green technologies and current issues on climate change.

6. Conclusions

This paper provides a narrative review of Malaysia's prospects and challenges in DER business model toward having zero-carbon emissions and energy security. Although fossil fuels still stood as dominant energy propelling sources in Malaysia, the government has shown its seriousness in converting them to clean energy for electricity production. The paper demonstrates that DER development is rapidly growing in Malaysia with the assist of proactive initiatives and fiscal incentives to attain energy independence. The pilot test for P2P energy trading and VPP currently being deployed has shown that DER's business prospects can inaugurate an efficient wholesale market structure. The same DER business models have been deployed in the world's leading RE capacity countries like Australia, Germany and the Netherlands through their specific RE directives and policies such as NEM and FIT. It also proves that the long-term RE vision of replacing fossil fuels had successfully improved the quality of life in those countries.

Despite the increasing number of DER integration, the intermittent behaviour exhibited by the renewables has led to common technical and non-technical challenges in the present power grid. The DSO must be ready to carry the TSO's responsibilities in managing dispersed distributed generation. The utility owners may suffer from the revenue reduction due to declining amount of electricity powered by fossil fuels plant. Still, at the same time, the plant must operate business as usual to maintain the grid. Furthermore, the high penetration of RE has caused difficulties in fixing the electricity tariff due to the declining levelized cost of electricity for solar PV. Therefore, technology maturity and innovative policy are essential to provide better control, efficiency and economical use of DER. The government must keep updating and regulating the RE directives and requirements to avoid any delays in progress with the current trend of energy transition. The policies planned should be significant to enable DER business models and prevent any imbalance in the electricity market and prices. The information discussed in this review article can be used for the benefit of the researchers, industries, energy users, and policymakers.

Acronyms

BESS	Battery Energy Storage System
CO_2	Carbon dioxide
DER	Distributed Energy Resources
DSO	Distribution System Operator
ESS	Energy Storage System
EVs	Electric Vehicles
FIT	Feed-In-Tariff
GHG	Greenhouse Gas
LSS	Large-Scale Solar
MyRER	Malaysia Renewable Energy Roadmap
NEM	Net-Energy-Metering
NOVA	Net Offset Virtual Aggregation
P2P	Peer-to-Peer
PHEV	Plug-In Hybrid Electric Vehicles
PPA	Power Purchase Agreement
PQ	Power Quality
PV	Photovoltaic
RE	Renewable Energy
SARE	Supply Agreement with Renewable Energy
SEDA	Sustainable Energy Development Authority
SELCO	Self-Consumption
SMP	System Marginal Price
TNB	Tenaga Nasional Berhad
TSO	Transmission System Operator
VNM	Virtual Net Metering

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