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Standards and Requirements for the Development of Battery Energy Storage System (BESS) Based Virtual Power Plant (VPP)

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Abstract

The power system is facing new challenges with anticipated higher penetration of Renewable Energy (RE) resources. Among others, Solar Power, other RE resources such as mini hydro, biomass, biogas and Battery Energy Storage System (BESS) is gaining popularity in terms of deployment. Virtual Power Plant (VPP) is relatively new concept of combining RE resources including BESS to serve as one power plant and able to be controlled by an aggregator system. VPP enhanced by BESS is capable in serving few utility and customers challenges. It has been identified that BESS can serve few applications such as to cut peak demand, energy arbitrage, spinning reserve, frequency regulation, and reducing the intermittency of renewable resources. It is foreseen that the role of BESS can be crucial with a higher increase of RE penetration of power system. This paper will cover technical and non-technical requirements for BESS and VPP development.

Keywords: Renewable Energy, Virtual Power Plant (VPP), Battery Energy Storage System (BESS), Biogas, Biomass

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1 Introduction

Tenaga Nasional Berhad (TNB), as the largest utility company in Peninsular Malaysia has built up a subsidiary TNB Renewables Sdn. Bhd. (TRe) in step with the industry's objective to be one of the world's top 10 energy providers below the Reimaging Tenaga transformation programme and also to be able to offer Renewable Energy (RE) solutions in line with the RE policy and goal of the government. TRe includes many local market RE development categories, namely Large Scale Solar (LSS) classified for plants over 30 MW, low cost RE schemes under 30 MW like biomass, biogas and mini-hydro plants, retail self-generation, based on solar rooftops, and innovative applications like Battery Energy Storage System (BESS) and Virtual Power Plant (VPP) (VPP). TRe is both an investment firm and an asset owner for those RE projects in the specific TNB industry. TRe is often proposed as a tool for achieving the RE objective of the government. At present, relative to the total generation mix, Malaysia has a low percentage of RE energy resources (if big hydro is not considered RE generation) and aims to achieve 20 percent penetration by 2025[1].

BESS has been identified as a technology that can serve multiple applications in power system [2,3,4]. The technical capability of BESS makes it a suitable candidate to serve several applications in the power system. This includes services to Grid System Operator (GSO) [5,6,7] as utility services and behind the meter (BTM) applications. For GSO applications, BESS has the capabilities to serve as frequency regulations, spinning reserve, and potentially be used as a black start, energy arbitrage and alternative to a peaking plant. While for utility services [8], BESS can be an alternative technology to defer substation upgrading and congestion relief. Finally, for behind the meter applications, BESS can be used to reduce customer bill by energy arbitrage, peak demand reduction and Demand Response (DR) services to GSO. BESS also can be backup power for customers. BESS or any other Distribution Energy Resources (DER) and connected via a software platform that can be operated as a VPP and offers more applications to power system.

This paper will discuss in detail the requirements in the implementation of BESS and VPP projects in Malaysia. The discussion will cover the technical requirements in terms of design and harmonising with the existing power system. This paper will also cover the non-technical requirements including to ensure the economics works for such investments and suggestion for policies and regulation for these technologies which currently have not been established in the Malaysian market.

2 Technical Requirements

In designing and determining the size of BESS, load profile analysis is conducted for the potential customers to be installed with BESS. The historical load profile is used to design the battery size and Power

Converter System (PCS) size. The sizing for both BESS and PCS have to consider the initial cost, maintenance, and depreciation factor. In order to determine the optimised size for BESS and PCS, the economic parameter is considered in the analysis. This includes the determination of the payback period and the return to the investment.

Tariff for C2 commercial customers has the highest rate compared to other tariff types in Peninsular Malaysia in terms of the peak demand charge. Peak demand is calculated based on the highest level of electrical demand monitored in a month period. The peak demand charge is for the utility to recover the invested asset for supplying electricity to customers. For Malaysian case, tariff setting mechanism and the policy on how utility recover capital investment is through Incentive Based Regulation (IBR) mechanism which the base tariff is reviewed in every three years and the adjustment for fuel price for power generation is adjusted twice yearly via Imbalance Cost Pass Through (ICPT) mechanism. For potential savings that can be utilised by customers is peak demand reduction, for instance, C2 customers' peak demand charge is RM 45.10 per month, by charging BESS during the lower tariff time which is the off-peak period at the price of 22.4 sen/kWh and discharging during peak period at the price od 36.5 sen/kWh, this will potentially minimize the cost of peak times and taking advantage of an energy arbitrage.

Figure 1 shows the sample of load data of a typical industrial customer. Figure 2 is the same load data after the calculation of optimisation has been applied to the load profile in anticipation of bill savings for the customer. With the application of the BESS, this sample customer which is from the C2 tariff type with peak off-peak tariff and peak demand charge is estimated to be reduced.

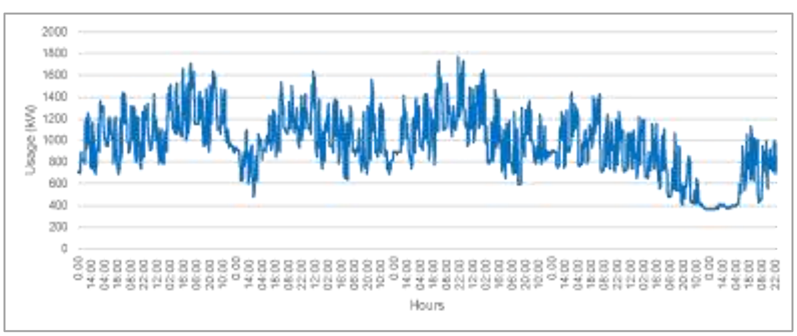

Figure 1 Load Demand Analysis for a Typical Industrial Customer

Figure 2 Load Demand Analysis for a Typical Industrial Customer after BESS Installation

The implementation of BESS and VPP in Malaysian power system has to comply with the Malaysia Grid Code (MGC) and Malaysia Distribution Code (MDC). Unfortunately, at this moment in Malaysia, there is no specific clause in the MGC and MDC related to BESS in terms of development or operation. Clauses under Distributed Generation can be used as a reference for BESS and VPP. Generation Planning criteria are listed in Table 1.

Table 1 Generation Planning Criteria

Capacity	Provision
Less than 5 MW	Malaysia Distribution Code
Between 5 MW and 15 MW	Malaysia Distribution Code And Malaysia Grid Code
More than 15 MW	Malaysia Distribution Code

Energy storage to be connected to the Distribution System must go through a system study analysis and required to meet to several standards including IEEE 1547 and IEC 62116 technical standards and should be compatible with the usual power system parameters including voltage level , short circuit current rating, frequency, current rating, and insulation level). The Distributed Generator with a Registered Capacity of 0.425 MW connected to the Distributor's MV (11kV) Distribution System is required to conduct a detailed Power System Studies (PSS) with the objectives of the PSS are as follows:

- to identify the connection scheme for the Generating plant which planned to be connected to the Distribution Network System.
- The effect of the new connection on the distribution system and the impact of the distribution network system on the operation of the generating plant should be examined.

- to identify mitigation to reduce impact identified in (2) above.
- to ensure no reverse power flow to the system

The scope of PSS study will cover load flow analysis which will cover penetration limit, voltage rise and loading of the distribution system. Short circuit analysis will give the fault current contribution. Besides that from the PSS study, the protection requirement can be determined such as anti-islanding and interlocking scheme.

In terms of safety, the Malaysian standard is to comply with IEC 62133 for battery safety [9, 10]. Originally this standard is meant for commercially used lithium-ion batteries excluding utility-scale but it can be the basis of testing for utility-scale energy storage. To date, there is no specific guideline or standard to address utility-scale BESS in Malaysia. The dedicated standard for the deployment of BESS is needed to ensure that the products used are safe and comply with local testing requirements.

In term of communication, installations of BESS and VPP have to comply to TNB's communication protocol i.e: IEC 60870 addressing telecommunication issues. These standards will ensure the harmonisation of new types of equipments and system with the existing power system. Table 2 summarises related standards in other jurisdiction related to Lithium-ion batteries deployment.

Table 2 Summary of Related Standards

No	Codes/ Standards	Description	Tests Checklist
1.	IEC 62133 [9]	This standard sets up a specific requirements and testing for portable sealed secondary lithium-ion batteries using non-acid electrolyte. Covering safety aspect under intended use and also misuse.	Tests include: Continuous low-rate of charging flow Stress test at a high ambient temperature Over-charging of battery External short circuit (individual cell) External short circuit (battery system) Forced discharge Vibration Thermal abuse Mechanical shock Freefall Crushing of cells

2.	IEC 61850-7- 420 [11]	This standard is for the communication network and utility automation, and logical nodes for Distributed Energy Resources (DER).	
3.	IEEE 1547 [12]	This IEEE Standard is designed for Distributed Energy Resources (DER) in terms of interconnection and interoperability of with electrical power systems peripherals and all possible Interfaces with the system.	This standard covers following elements: Performance Operation Testing Power quality Islanding Safety Operation & Maintenance Response to abnormal conditions Test specifications and requirements for the design Production Installation evaluation Commissioning Periodic Test
4.	IEEE 2030 [12]	This is the IEEE Standard for Smart Grid in terms of the interoperability of any energy technology. This standard also covers the Information Technology (IT) Operation in the same operation with Electric Power System (EPS), End-User Applications, and all types of loads.	
5.	IEC 62619 [13]	This safety standard specifies the test requirement for safe operation of secondary batteries (Lithium-ion type). Specifically used for industrial customers.	Tests include: External short-circuit test (single cell or cell block) Internal short-circuit test (single cell) Overcharge test (single cell or cell block) Forced discharge test (single cell or cell block) Overcharge control of voltage parameter (for battery system) Overcharge control of current parameter (for battery system) Overheating control (for battery system) Propagation test (battery system) Drop test (cell or cell block, and battery system) Impact test (cell or cell block) Thermal abuse test (cell or cell block)

6.	IEC 62620 [13]	This standard cover batteries containing alkaline as electrolytes as well as other type of electrolytes. Specifically for industrial customers.	Tests included: Discharge performance at temperature +25°C (rated capacity) Discharge performance at low temperature level High permissible rate for current flow Charge (capacity) retention and recovery process Measurement of the internal Alternating Current (AC) resistance Measurement of the internal Direct Current (DC) resistance Endurance in cycles of charge and discharge Endurance in storage at constant voltage level (permanent charge life)
7.	IEC 60870 [13]	This standard addresses telecontrol issues used for controlling grid transmission power peripherals and other types of widespread control system.	
8.	IEC 63056 NWP [14]	This standard covers safety requirements for secondary cells and lithium ion batteries including alkaline electrolytes or any non-acid electrolytes.	
9.	UL 1642 [15]	This standard and requirements cover for primary (non-rechargeable) lithium batteries and secondary (rechargeable) lithium batteries. The batteries are used for power source in products available in the market. Batteries cover the type that possibly contain metallic lithium, lithium alloy, or lithium ion. Product can consist of a single electrochemical cell, or more cells connected electrically in series or parallel connection. It will convert chemical energy into electrical energy via an irreversible or reversible chemical reaction - The requirements cover lithium batteries that are designed to be replaced by a certified technician or replaced by any battery users. - For the batteries that are designed to be replaced by dedicated technician (technician-replaceable), this type of batteries, can only	Tests included: Short-Circuit Test Abnormal Charging Test Forced Discharge Test Temperature Cycling Test Low Pressure (Altitude) Test Projectile Test Crush Test Shock Test Impact Test Heating Test Vibration Test

		be replaced by a person who has been trained and meet a certain level of knowledge in repairing and servicing the product. -For the batteries that are designed and intended to be used and serviced by a user (user-replaceable) where repairing and servising can be done by user. - The requirements is for technician-replaceable lithium batteries for metallic lithium content of 5g or less. A battery containing more than 5g of lithium is evaluated based on compliance with the requirements that is stipulated in this standard. If these batteries are applicable, further testing is required whether the battery is suitable and acceptable for the required purposes. - The requirements also cover user-replaceable type of lithium batteries with 4g content of metallic lithium or less with not more than 1g of metallic lithium in each individual electrochemical cell. For a battery cell that contain more than 4g or a cell containing more than 1g lithium further testing is required whether the battery is suitable and acceptable for the intended uses.	
10	UL 2054 [16]	This standard is for residential and commercial usage of batteries. The requirements cover batteries with portable primary (non-rechargeable) and secondary (rechargeable) batteries used as a power source in any products/premisses. These batteries can consist of either a single electrochemical cell, or more cells connected in series, parallel, or both configurations that can possibly convert chemical energy into electrical energy by a chemical reaction. This standard is intended to : Adress safety reasons to avoid fire hazard risk and explosion caused by the product. Cover batteries for general usage only. This standard does not include requirements originally covered by product standard. Reduce the injury risk to the person working with batteries due to fire or explosion resulting from activities related to transportation, storing, discarding and disposal of batteries. On safety aspect, this standard does not include the toxicity hazard risk from the ingestion process of a battery or its other contents, nor the injury risk due to exposure to open the battery and open access to its contents.	Tests included: Battery Pack Component Temperature Test Battery Pack Surface Temperature Test Short-Circuit Test Forced-Discharge Test Limited Power Source Test Crush Test Impact Test Vibration Test Shock Test 250 Newton (N) Steady Force Test (Battery Enclosure Test) Mold Stress Relief Test (Battery Enclosure Test) Abnormal Charging Test Abusive Overcharge Test Drop Impact Test (Battery Enclosure Test) Projectile Test Heating Test Temperature Cycling Test

3 Non Technical Requirements

As previously discussed, BESS is able to serve several applications for the power system. In order to ensure positive economics, value stacking of BESS will improve value for the investments. Figure 3 shows a decrease in BESS costs projections. Historically, BESS has shown a 5% decrease yearly. With the price projected by Bloomberg New Energy Finance (BNEF), it is projected that the BESS project with the right incentives and revenue stream can be commercially viable in Malaysia.

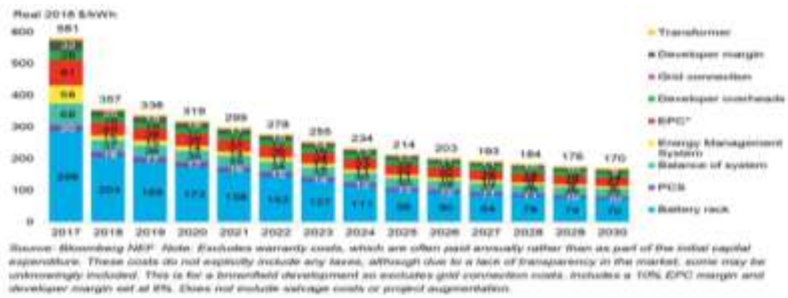

Figure 3 Capital costs for 20MW/80MWh AC Fully-installed Energy Storage System [17].

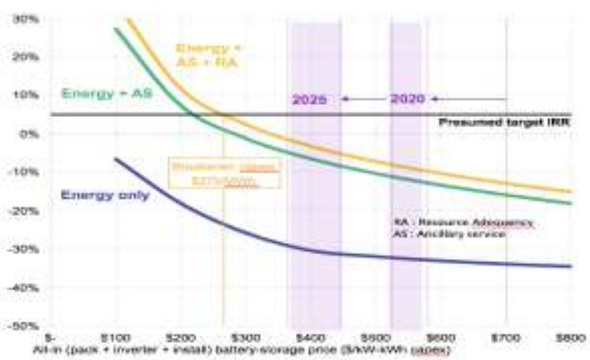

Figure 4 Project IRR for a stationary battery-storage system in California Independent System Operator (CAISO) – selling power, ancillary services and resource adequacy, based on 2016 prices (% – real returns) [16].

Analysis from Bloomberg in Figure 3 shows the capital investments needed for a typical 20MW/80MWh fully installed BESS. This figure also shows the decreasing trend for the cost elements. It is projected that the price will decrease at a very significant amount and will reach $170/kWh by 2030. From Figure 4, it can be concluded that in order for a project to be viable, the revenue stream must come from several sources. To achieve at least 5% Internal Rate of Return (IRR), the revenue stack must be coming from Energy Arbitrage (EA), Ancillary Services (AS) and also Resource Adequacy (RA). EA is purely the opportunity to buy energy at a low price and sell at a higher price. AS is the payment from the market whenever the battery offers services to the market. RA payments are decided via bilateral contracts with the utilities. In terms of capital investment, the BESS total system must reach the price of around $USD 275/kW to achieve break-even. Project return will increase as the capital expenditure (CAPEX) decrease. For the Malaysian case, it is still unclear on the mechanism to determine the cost for AS in order to evaluate the business case for BESS investment. In Malaysia, EA and AS services are currently remunerated via Power Purchase Agreements (PPA) between off-taker which is TNB and the power generation plants. The market for such services still does not exist in Malaysia. Hence, appropriate incentives for BESS developers is currently important to ensure a steady revenue stream to the investments.

4 Conclusions

In conclusion, the development of BESS in Malaysia is still in the early stage. Most projects are still on a research basis and not ready for a full commercial project. Main obstacles for a commercial project is mainly related to the absence of supporting incentives to enhance revenue stack of the project development. Looking at the rapid development for BESS in other jurisdictions, it is foreseen that it will drive down the BESS price as projected. Technical standards specifically tailored to utility-scale BESS has also not been established in Malaysia and should be looked into in anticipation of the technology penetration in Malaysia in the future. Several policies from other countries like Korea can be adopted in order to expedite the deployment of BESS in Malaysia. In line with Malaysian Government target to achieve 20% RE penetration by 2025, this technology should be seriously considered for bigger scale deployment due to the capabilities to serve and offer several solution to the grid.

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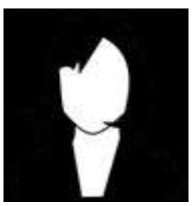

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