HANDBOOK FOR

ENERGY STORAGE SYSTEMS

Energy Market Authority

Smart Energy, Sustainable Future

ENERGY MARKET AUTHORITY

Smart Energy, Sustainable Future

ABOUT THE ENERGY MARKET AUTHORITY

The Energy Market Authority ("EMA") is a statutory board under the Ministry of Trade and Industry. Our main goals are to ensure a reliable and secure energy supply, promote effective competition in the energy market, and develop a dynamic energy sector in Singapore. Through our work, EMA seeks to forge a progressive energy landscape for sustained growth.

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FOREWORD

During the 12th Singapore International Energy Week in 2019, Minister for Trade & Industry, Mr Chan Chun Sing spoke about Singapore's Energy Story. This was about transcending the challenges of the energy trilemma - to keep our energy supply affordable, reliable and sustainable. He also announced that Singapore would set its installed solar capacity target to at least 2 gigawatt-peak by 2030, enough to power about 350,000 households for a year.

Singapore has limited renewable energy options, and solar remains Singapore's most viable clean energy source. However, it is intermittent by nature and its output is affected by environmental and weather conditions such as cloud cover. To overcome this challenge, we are deploying Energy Storage Systems ("ESS") which has the ability to store energy for later use. ESS not only addresses solar intermittency, but also enhances grid resilience by actively managing mismatches between electricity supply and demand. As part of the Energy Story, Singapore has put forth a target to deploy 200 megawatts of ESS beyond 2025 to support the increased deployment of solar.

To facilitate ESS adoption in Singapore, EMA has worked with various regulatory agencies and industry stakeholders to develop this Handbook for Energy Storage Systems. This handbook outlines various applications for ESS in Singapore, with a focus on Battery ESS ("BESS") being the dominant technology for Singapore in the near term. It also serves as a comprehensive guide for those who wish to install BESS in Singapore.

We hope that this handbook will help readers better understand the opportunities presented by ESS and encourage the support of ESS deployment in Singapore.

MR BERNARD NEE

Deputy Chief Executive
Energy Planning and Development Division
Energy Market Authority
Singapore

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1. Durapower Technology (Singapore) Pte Ltd
2. Energy Market Company Pte Ltd
3. GenPlus Pte Ltd
4. Singapore Civil Defence Force
5. SP Group

Cover photo courtesy of Singapore Tourism Board

ABBREVIATIONS AND ACRONYMS

Alternating Current	AC
Battery Energy Storage Systems	BESS
Battery Management System	BMS
Battery Thermal Management System	BTMS
Depth of Discharge	DOD
Direct Current	DC
Electrical Installation	EI
Energy Management System	EMS
Energy Market Company	EMC
Energy Storage Systems	ESS
Factory Acceptance Test	FAT
Hertz	Hz
Intermittent Generation Sources	IGS
Kilovolt-amperes	kVA
Kilowatt-peak	kWp
Licensed Electrical Worker	LEW
Market Participant	MP
Megawatt	MW
Megawatt-hour	MWh
Operation and Maintenance	O&M
Photovoltaic	PV
Power Conversion System	PCS
Qualified Person	QP
Registered Inspector	RI
Singapore Civil Defence Force	SCDF
Singapore Tourism Board	STB
Site Acceptance Test	SAT
SP Power Grid	SPPG
SP Services	SPS
State-of-Charge	SOC
State-of-Health	SOH
System Integrator	SI

ENERGY STORAGE SYSTEMS

01

1.1 Introduction

Energy Storage Systems ("ESS") is a group of systems put together that can store and release energy as and when required. It is essential in enabling the energy transition to a more sustainable energy mix by incorporating more renewable energy sources that are intermittent in nature - such as solar and wind. Such energy sources are also commonly known as intermittent generation sources ("IGS").

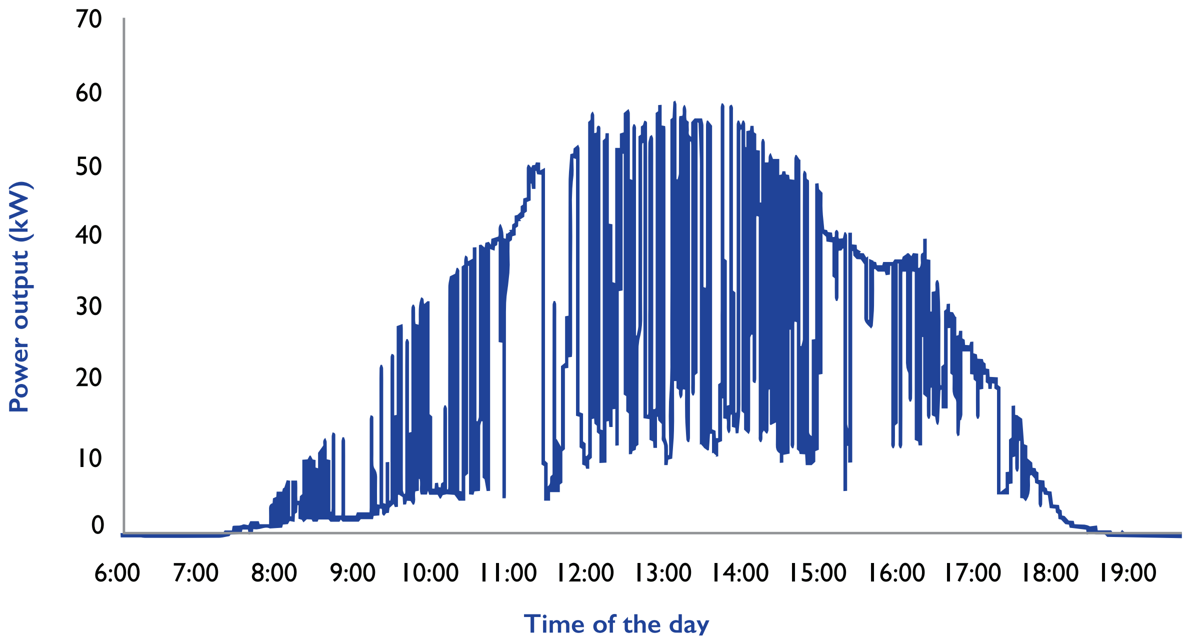


Figure 1: Power output of a 63 kWp solar PV system on a typical day in Singapore

As shown in Figure 1, the power output of a 63 kilowatt-peak ("kWp") solar photovoltaic ("PV") system deployed in Singapore fluctuates throughout the day. These fluctuations are a result of Singapore's tropical weather conditions. For example, extensive cloud cover on rainy days can cause a significant drop in solar power output. Such variations in solar power output can cause imbalances in electricity supply and demand and affect the stability of the power grid.

To ensure that the power system remains stable and reliable, power system operators will require power generators to be more flexible and responsive to address the intermittency from IGS. ESS's unique ability to store energy produced at a particular time for later use can help the system respond to power fluctuations when required. This will help to smoothen the variable power output and facilitate the integration of IGS into the power grid.

1.2 Types of ESS Technologies

ESS technologies can be classified into five categories based on the form in which energy is stored.

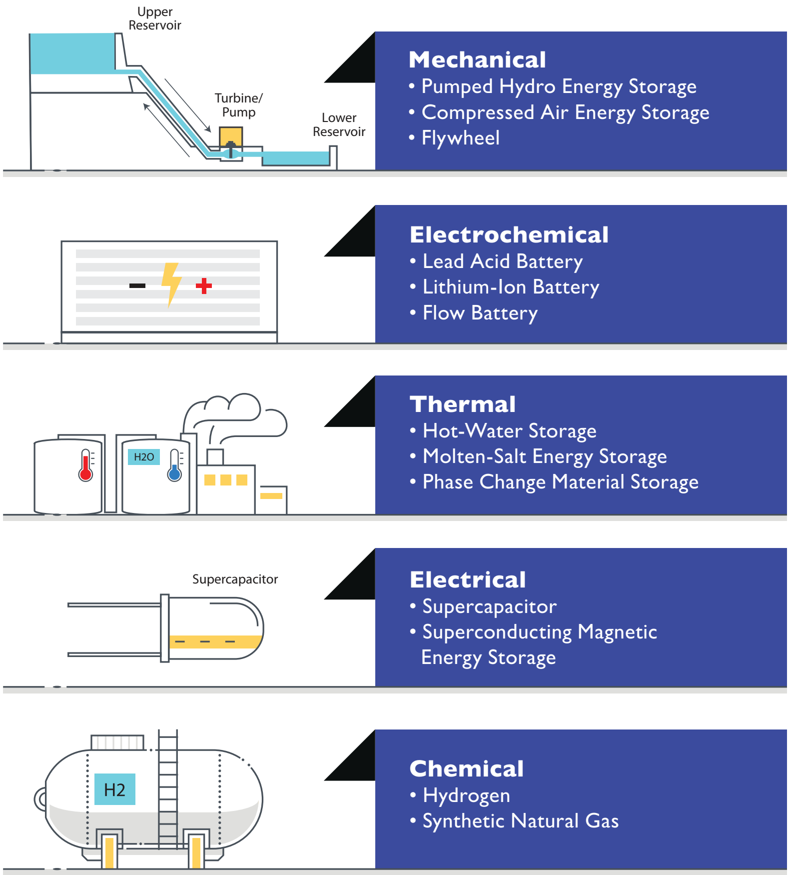


Figure 2: Types of ESS Technologies[1]

1.3 Characteristics of ESS

ESS is defined by two key characteristics – power capacity in Watt and storage capacity in Watt-hour. Power capacity measures the instantaneous power output of the ESS whereas energy capacity measures the maximum amount of energy that can be stored.

Depending on their characteristics, different types of ESS are deployed for different applications. For example,

i. Flywheel, which spins at high speed to store energy as rotational energy, is more effective in applications where high-power output is required for short durations.

ii. Pumped Hydro Energy Storage, which pumps large amount of water to a higher-level reservoir, storing as potential energy, is more suitable for applications where energy is required for sustained periods.

In comparison, electrochemical ESS such as Lithium-Ion Battery can support a wider range of applications. Their power and storage capacities are at a more intermediate level which allow for discharging power at a relatively high output for a reasonable time period.

[1] *Electricity Storage Factbook, SBC Energy Institute 2013*

1.4 Applications of ESS in Singapore

ESS can be deployed for several applications, ranging from reducing consumers' electricity costs, generating revenue through energy market participation, to provision of ancillary services for the power grid.

As this handbook provides information on ESS deployment in Singapore, the applications listed below are specific to Singapore's power systems.

Energy Market Participation

- **Energy Arbitrage**
- **Mitigating Intermittency of IGS**
- **Improving Performance of Gas Turbines**

Provision of Ancillary Services

- **Regulation**
- **Reserves**
- **Demand Side Participation**

Consumer Energy Management

- **Peak Shaving**
- **Emergency Power Supply**
- **Defer Assets Upgrade**

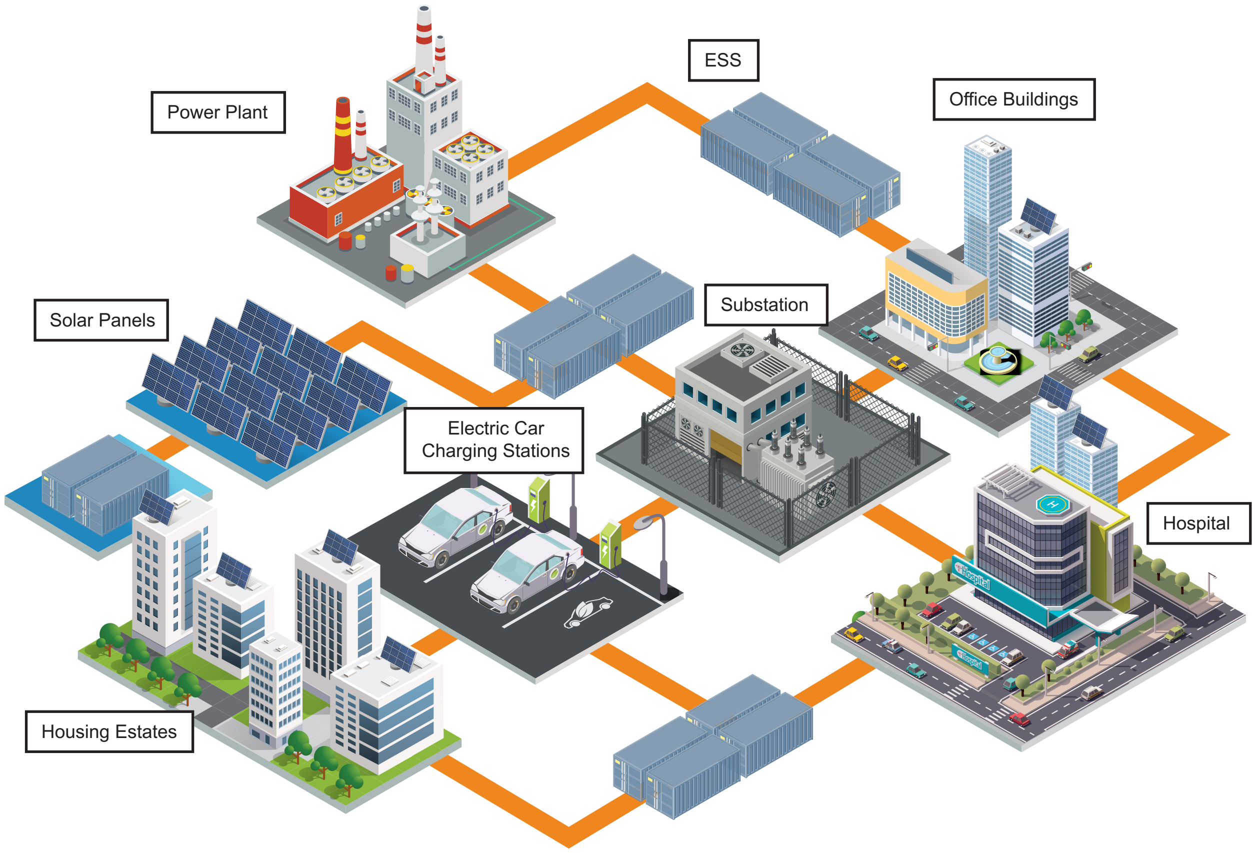


Figure 3: Applications of ESS in Singapore

1.4.1 Energy Market Participation

i. Energy Arbitrage

Owners of ESS can earn additional revenue by buying and storing energy in ESS when electricity prices are low and discharging and selling energy to the power grid when electricity prices are high.

ii. Mitigating Intermittency of IGS

ESS can be co-located with IGS to address intermittency by providing localised ramping during periods of fluctuating output. It can partially or fully absorb the intermittency of the IGS by charging and discharging accordingly, thus smoothening the fluctuations.

iii. Improving Performance of Gas Turbines

The pairing of ESS with gas turbines can provide more flexible operations which lead to higher fuel efficiency, reducing maintenance costs and emissions. ESS can be used to provide reserves, allowing gas turbines to run at a more optimal load to provide for energy.

1.4.2 Provision of Ancillary Services

i. Regulation

Regulation is a service provided by generators to fine-tune frequency variations due to imbalances between load and the output from generation facilities. It is a frequency-following service that maintains the system frequency within the allowable range of 50 ± 0.2 Hz. Due to its rapid response characteristic, ESS can be deployed as a regulation resource to cover the second-to-second variations.

ii. Reserves

Reserves are generation capacity that can be drawn upon when there is an unforeseen disruption of supply. Following a loss in generation, reserves are required and ESS can be deployed as a stand-by generator in the power system to arrest the fall in system frequency.

In Singapore, there are two types of reserves categorised by their response time.

a. Primary Reserve

A reserve class that can be called upon within a 9-second response time and sustained for an additional 9 minutes and 51 seconds.

b. Contingency Reserve

A reserve class that can be called upon within a 10-minute response time and sustained for at least 30 minutes.

iii. Demand Side Participation

In the event of imbalances between electricity demand and supply, consumers are able to participate in Demand Side Participation programmes to reduce their load. ESS, when charged, can act as a power source and in turn reduce load from the grid.

There are two types of Demand Side Participation Programmes in Singapore today.

a. Demand Response Programme

The programme allows consumers to participate in the National Electricity Market of Singapore through reducing electricity demand via demand-side bidding in exchange for a share of the system-wide benefits as a result of their actions.

b. Interruptible Load Scheme

The scheme allows consumers to participate in the reserves market by curtailing electricity demand voluntarily as a substitute for reserves. If scheduled, the consumer would be paid the prevailing market price for reserves.

1.4.3 Consumer Energy Management

i. Peak Shaving

ESS can reduce consumers' overall electricity costs by storing energy during off-peak periods when electricity prices are low for later use when the electricity prices are high during the peak periods.

ii. Emergency Power Supply

ESS can act as a source of emergency power supply when there is a power outage. This is essential for places such as data centres or hospitals where power supply is constantly needed. They can also act as transitional power supply as diesel generators are ramped up during the outage.

iii. Defer Assets Upgrade

ESS can defer the cost of upgrading existing transformers and substations by meeting short-term peak load demand. In certain circumstances, this may be more cost-effective than building new infrastructure.

BATTERY ENERGY STORAGE SYSTEMS

02

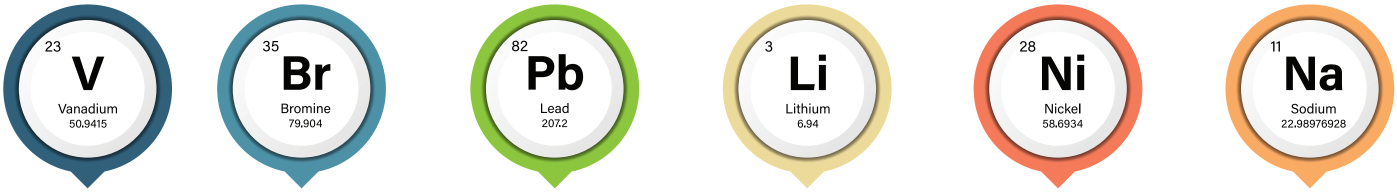
2.1 Introduction

Battery ESS ("BESS") is an electrochemical ESS where stored chemical energy can be converted to electrical energy when required. It is usually deployed in modularised container and has less geographical restrictions when compared to other types of ESS. For example, Pumped Hydro Energy Storage is limited to geographic areas with height variations and large water bodies, while Compressed Air Energy Storage typically requires underground caverns.

The compact nature of BESS allows for high scalability and versatile deployment. Examples of utility-scale BESS deployments in other jurisdictions are given below:

Figure 4: Global BESS deployments

2.2 Types of BESS



Flow Battery Redox/Hybrid

- Vanadium
- Polysulfide-Bromine
- Zinc-Bromine

Lead Acid Battery

- Sealed Lead Acid
- Valve Regulated Lead Acid

Lithium-Ion Battery

- Lithium Cobalt Oxide
- Lithium Iron Phosphate
- Lithium Manganese Iron Phosphate
- Lithium Manganese Oxide
- Lithium Nickel Cobalt Aluminium Oxide
- Lithium Nickel Manganese Cobalt Oxide
- Lithium Titanate

Nickel-based Battery

- Nickel-Cadmium
- Nickel-Metal Hydride

Sodium Battery

- Sodium-Nickel-Chloride
- Sodium-Sulfur

Figure 5: Examples of BESS and battery chemistries[2]

There are different types of BESS and battery chemistries available in the market. Each has its own unique advantages and disadvantages. In the near term, Lithium-Ion Battery is likely to continue to dominate the market given its cost, energy density and relatively faster response time. The price curve of a Lithium-Ion Battery is largely driven by the development of batteries in electric vehicles, and consumer electronics such as laptops and mobile phones.

Figure 6: Image of a Lithium-Ion Battery

[2] *Handbook on Battery Energy Storage System, Asian Development Bank 2018*

2.3 BESS Sub-Systems

A BESS typically consists of three sub-systems, namely:

i) Battery System which includes Battery Rack, Battery Management System ("BMS") and Battery Thermal Management System ("BTMS");

ii) Power Conversion System ("PCS"); and

iii) Energy Management System ("EMS").

Battery Rack

The Battery Rack is made up of several battery cells and modules connected in series or parallel.

Power Conversion System

The PCS converts alternating current ("AC") to direct current ("DC"), and vice versa, to allow power flow between the BESS and the grid.

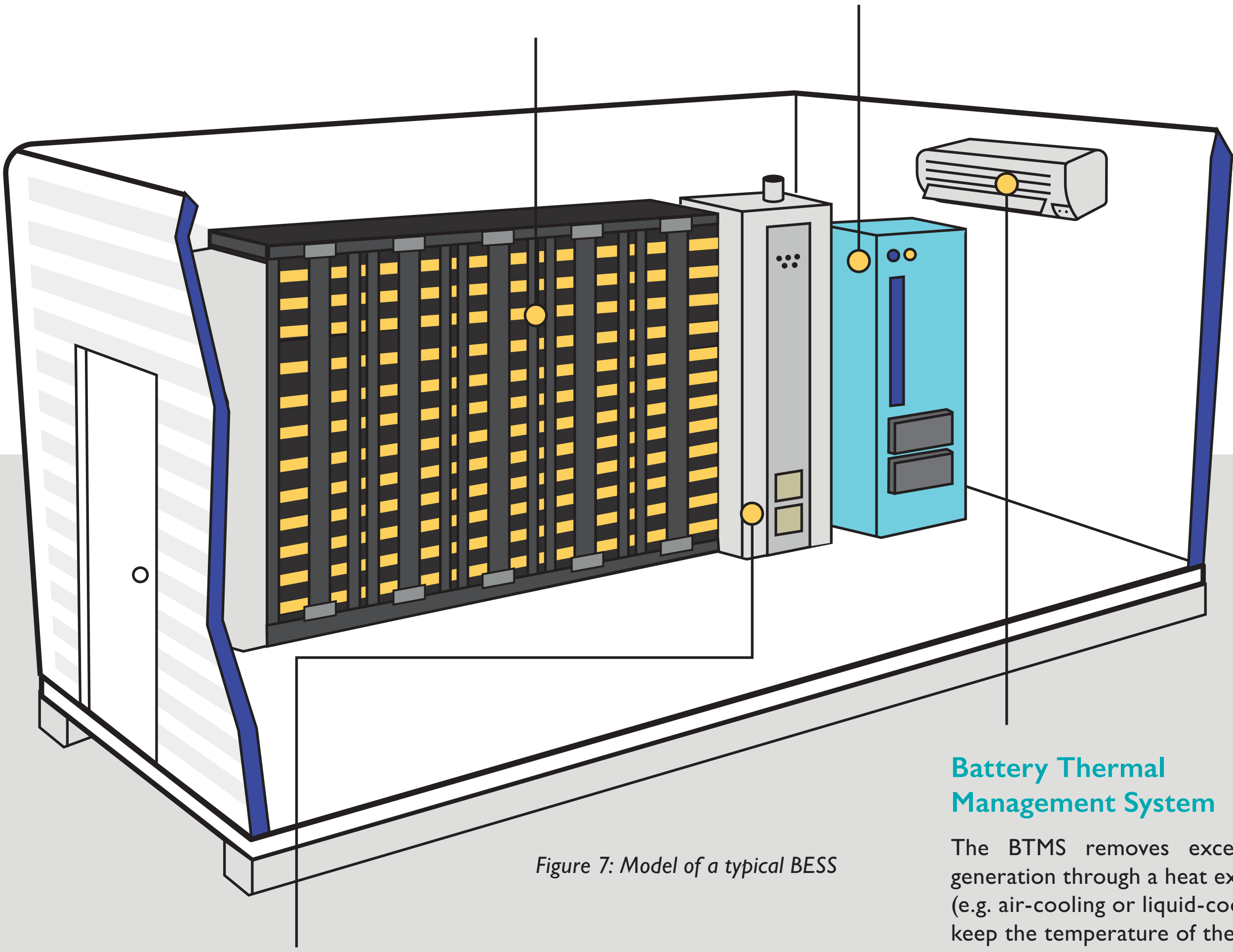


Figure 7: Model of a typical BESS

Battery Thermal Management System

The BTMS removes excess heat generation through a heat exchanger (e.g. air-cooling or liquid-cooling) to keep the temperature of the battery within the optimum limits and prevent overheating.

Energy Management System

The EMS monitors, controls and optimises the overall power flow and distribution of the BESS based on the identified applications.

Battery Management System

The BMS protects the battery from harmful operation and maximises its lifespan by constantly monitoring the battery's parameters such as voltage, current, temperature, State-of-Charge[3] ("SOC") and State-of-Health[4] ("SOH"), and ensuring they are within operating specifications.

[3] *State-of-Charge measures the available capacity as a percentage of the maximum capacity.*

[4] *State-of-Health measures the performance and conditions of the battery in comparison to a new battery.*

BESS REGULATORY REQUIREMENTS

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3.1 Fire Safety Certification

Thermal runaway occurs when excessive heat is generated and accumulated within the battery. This can happen due to poor system design or mishandling, leading to the build-up of heat and flammable gas such as hydrogen.

Under the Fire Safety Act, the owner of the BESS has to engage a Qualified Person ("QP") who is a registered architect or professional engineer. The appointed QP is required to seek SCDF's approval on the plan for fire safety works before the installation of BESS.

Once the works are completed in accordance with SCDF's requirements, the owner will need to engage a Registered Inspector ("RI") to inspect and certify the fire safety works. With the Inspection Certificate issued by the RI, the QP can then apply for the Fire Safety Certificate through SCDF, on behalf of the owner.

The application procedures for the Fire Safety Certificate are available at SCDF's website. If the QP/ owner wishes to seek any clarifications, he/she can arrange a consultation with SCDF.

3.2 Electrical Installation Licence

Under the Electricity Act, an Electrical Installation ("EI") Licence is required for all non-domestic electrical installation with approved load exceeding 45 kilovolt-amperes ("kVA"). It is a requirement for owners of electrical installations to appoint a Licensed Electrical Worker[5] ("LEW") to take charge of their electrical installations.

The EI Licence will be issued to owners to operate their electrical installation after the appointed LEW has inspected, checked and certified the fitness of the electrical installation under his charge.

If the owner has an existing EI Licence and the BESS is to be connected as part of the current electrical installation, the BESS shall be covered under the same EI Licence issued to the owner. The appointed LEW will have to update the single-line diagram on EMA's ELISE website.

More information is available in EMA's Handbook: Application of Electrical Installation Licence.

[5] *A licensed electrical worker is a person who is technically competent in carrying out electrical work and licensed by EMA to carry out electrical work. LEWs and their contact particulars can be found on EMA's ELISE website.*

3.3 Electricity Generation or Wholesaler Licence

Under EMA's current regulatory framework, the type of licence required by the BESS, where one unit of BESS is defined as one or more batteries connected to a single PCS, is dependent on the name-plate rating of the BESS. It is determined based on the lower of:

a. The aggregate of the batteries' installed capacity; or

b. The AC capacity of its PCS.

i. Any person who owns a BESS that is either directly or indirectly connected to the grid will be required to be licensed under an Electricity Generation Licence, or Wholesaler Licence, based on the following:

Name-plate rating per unit of BESS	Less than 1 MW	1 MW or more but less than 10 MW	10 MW or more
Type of Electricity Generation Licence Required	Exempted	Wholesaler Licence	Generation Licence

For multiple units of BESS, each unit having its own PCS and connected to the same grid connection point, the licensing requirement will be based on the name-plate rating of each unit of BESS.

ii. For BESS that is paired with IGS[6] (i.e. sharing the same PCS/inverter), such a setup will be considered as a single generating unit with name-plate capacity determined as the lower of:

a. The aggregate installed capacity of BESS and IGS; or

b. The AC capacity of the shared PCS/inverter.

Application for the Electricity Generation Licence or Wholesaler Licence can be made via the GoBusiness Licensing Portal on EMA's website.

[6] *Where the AC electricity output of an IGS and a BESS is through separate inverters and PCSs, which are connected in parallel at the same grid connection point, the licensing requirement for the IGS and BESS will be assessed individually.*

3.4 Connection to the Power Grid

The connection of the BESS to the power grid for all new or existing installations will require the appointed LEW to complete an online application form and submit the relevant documents to SP Services ("SPS") via SP's eBusiness Portal. Thereafter, the LEW will need to consult SP PowerGrid ("SPPG") on the connection schemes and technical requirements.

As part of the submission, the appointed LEW is required to submit installation details, such as the type of BESS, name-plate capacity, application and installation location. The details collected will be recorded in a registry maintained by SPPG which will be used to track BESS installations, and assess the level of BESS in the system and its impact on the grid. This is important for the purpose of ensuring power system stability, both at the localised and system level. The LEW is required to inform SPPG before they disconnect or retrofit any grid-connected BESS installations. This ensures that information in the BESS Registry is kept up to date.

More information is available in SP Group's Handbook: How to Apply for Electricity Connection.

BESS's installation will follow the existing requirements in Transmission Code and Metering Code which are published at EMA's website.

3.5 Market Participation

Under the existing Market Rules, the BESS is required to be registered with EMC as a Market Participant ("MP")[7] if the owner wishes to participate in the wholesale market and provide ancillary services.

To register as a MP, interested parties are required to submit relevant documents to EMC. The application procedures for MP registration are set out in the Market Administration Market Manual – Registration and Authorisation. MPs are to comply with the Market Rules.

[7] *For contestable consumers with embedded ESS capacity below 10 MW who participate only in the energy market, they can register under the Enhanced Central Intermediary Scheme (ECIS) with SP Services and be paid at prevailing half-hourly average nodal prices.*

GUIDE TO BESS DEPLOYMENT

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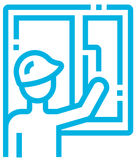
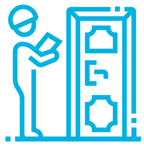
4.1 Role of a BESS System Integrator

To deploy a BESS, the owner can engage a BESS System Integrator ("SI"). The appointed SI will be responsible for the following:



- Design and install the BESS, which includes integration of hardware and software.

- Ensure the Factory Acceptance Test ("FAT") and Site Acceptance Test ("SAT") are conducted to detect any possible faults.



- Conduct regular inspections and maintenance works after commissioning.

4.2 Appointing a BESS System Integrator

Those who wish to deploy a BESS through engaging a BESS SI may wish to take note of the recommended procedures[8].

STEP 1

Gathering Preliminary Design Requirements

Before appointing a SI, the owner shall identify the applications for the BESS and compile a list of design requirements such as the load profiles of the facility, installation site layout, ambient conditions, etc.

STEP 2

Battery Chemistry and Sizing of the BESS

The preliminary design requirements shall be provided to potential SIs for their recommendations on the appropriate battery chemistry and the optimal sizing of BESS. Alternatively, the owner can engage an external consultant to conduct the analysis.

STEP 3

Selection of SI

Selecting bids submitted by SIs for the BESS's engineering, procurement and construction processes is typically done through a tendering process which considers the following factors:

i. Experience and Track Record

The experience and track record of the SI and the battery manufacturer play an important role in the selection of bids. Owners are encouraged to review the battery performance in terms of specifications, safety and testing certification standards. Examples of standards include:

- IEC 62619 Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries, for use in industrial applications;
- UL 9540A Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems.

[8] *Please refer to Appendix A. Design and Installation Checklist for more details.*

ii. Design of BESS

The proposed BESS can either be a turnkey solution or a customised design. The owner shall evaluate and ensure that the proposed BESS is designed to fulfil his/her requirements. Some of the key parameters include the operating cycles, round trip efficiency, degradation per year, etc.

In addition, it is also important to include safety measures in the design of BESS to mitigate fire risks and electrical hazards. Some safety measures include:

Adhering to Singapore's Electrical Energy Storage Technical Reference.

Deploying fire detection systems such as sensors to monitor temperature and humidity, smoke and gas detectors to detect build-up of gas.

Deploying additional fire suppression systems (e.g. powder extinguisher).

Having a reliable BMS for early detection of overvoltage or high temperature.

Having an effective BTMS to remove excess heat.

Adopting protection methods to prevent short circuit, overvoltage and over current.

iii. Cost

The total cost for the BESS stated in the bids shall include equipment cost (i.e. hardware & software), installation cost, maintenance cost, etc.

iv. Warranty

Depending on its applications, a BESS is typically designed to last for more than 10 years, with two levels of coverage:

a. System Warranty which warrants the workmanship of the BESS's installation to ensure the performance of the BESS.

b. Product Warranty which warrants the respective equipment parts.

However, the details of the warranty can vary widely depending on the battery chemistries, manufacturers, operating ambient conditions, charging-discharging characteristics such as cycle life, C-rate[9] or Depth of Discharge[10] ("DOD"), etc. For example, the warranty period tends to be lower if the C-rate is higher.

v. Maintenance Service and Support

Regular maintenance of the BESS, including software updates, is essential to maximise its lifespan. Based on individual needs, the SI can provide scheduled and/or unscheduled maintenance. As part of the maintenance package, the owner can request for the inclusion of the cost of repairs and replacement parts.

9 *C-rate measures the rate of discharge relative to the maximum capacity.*
10 *Depth of Discharge measures the capacity that has been discharged as a percentage of the maximum capacity.*

OPERATION AND MAINTENANCE

05

5.1 Operation of BESS

Prior to the handover of BESS, the SI shall conduct basic operation and maintenance ("O&M") training for the owner and his/her operator. This is to be supplemented with an O&M manual to cover the specification of the BESS, software manual, troubleshooting instructions and warranty information.

As the BESS will be controlled by the EMS, minimal operating procedures are required. The BESS operator shall monitor the performance of the BESS and check regularly for any error messages to ensure safe operation. This can be done via a monitoring software provided by the SI as part of the BMS. Typically, the monitoring software will record the various parameters such as power, current, SOC, cell voltage differences and temperature.

Figure 8: Screenshots of a BMS [Courtesy of GenPlus Pte Ltd]

When the BESS is not in operation for an extended period, it is recommended for the BESS operator to store the battery in a cool and ventilated environment, and to recharge and discharge the battery regularly to prevent the degradation of battery cells.

5.2 Recommended Inspections

The following table provides some common inspections for the BESS (i.e. non-exhaustive) as recommended by SI. For more details, the operator can refer to the O&M manual and/or to consult his/her SI.

Components	Recommended Checks:
Battery System	• Battery modules for any abnormal cell behavior (e.g. smell) • BMS for any error messages • Ventilation fan for any impeded airflow • Electrolyte leakages or water ingress • Worn-out or damaged cables connecting to the battery modules
Liquid Cooling BTMS	• Sufficient coolant or refrigerant • Worn-out or damaged water hose
PCS	• Terminal connections for burnt marks, hot spots and loose connections • Water ingress • System parameters (e.g. AC voltages, operating temperature) to ensure they are within appropriate range
Cabling	• Cables for discoloration, wear and tear • Cable terminals for burnt marks, hot spots or loose connections
Earthing	• Earthing cable for discoloration, wear and tear • Earthing cable terminals for burnt marks, hot spots or loose connections • Continuity of the earthing cable

CONCLUSION

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6.1 Energy Future of Singapore

As Singapore progresses towards a cleaner and more efficient energy future, ESS is an important asset that can provide multiple benefits such as supporting higher penetration of IGS in our power grid and contributing to grid stability. It plays a vital role to meet Singapore's 2030 solar target.

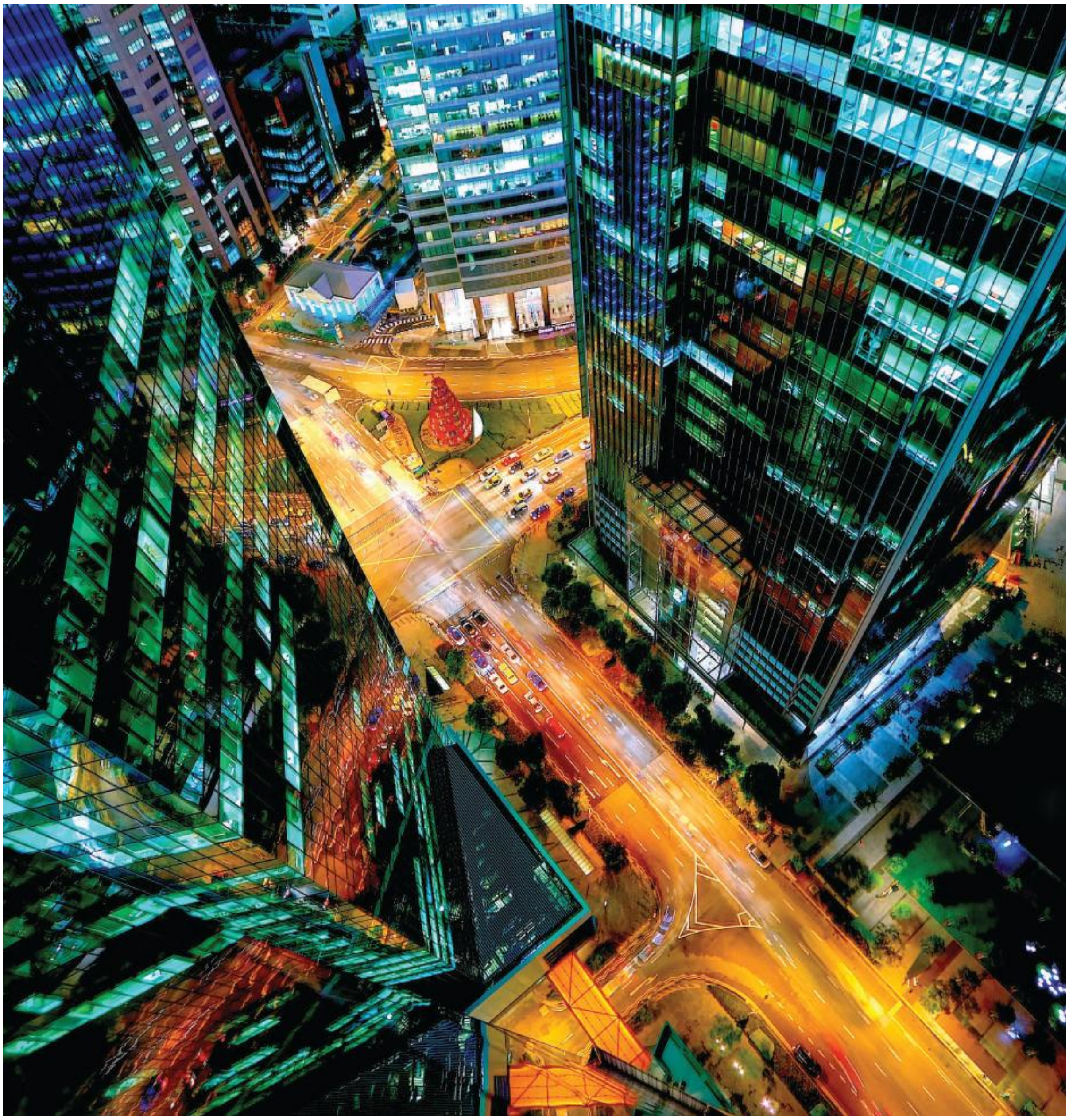

Photo Courtesy of STB

Against the backdrop of a growing interest in BESS due to its favourable characteristics, EMA has developed this handbook to support and facilitate the deployment of ESS in Singapore. With your continued support, we will continue to update this handbook as ESS technologies, policy and regulatory frameworks evolve. EMA welcomes feedback and suggestion for future editions.

APPENDICES

Appendix A. Design and Installation Checklist

You may refer to the following checklist[11] once you have decided to install BESS in your premises.

No.	Design and Installation Checklist	Check Box
1.	Define needs and applications.	☐
2.	Set your budget.	☐
3.	Select a location and perform a site survey for available space.	☐
4.	Compile a preliminary list of design requirements.	☐
5.	Select a SI. The appointed SI can recommend the appropriate battery chemistry and sizing of BESS. He/she will be responsible for the overall design and installation of the BESS.	☐
6.	Engage a LEW. The appointed LEW will be responsible for the design and implementation of the connection of your BESS to the electrical installation and/or power grid.	☐
7.	SI and/or LEW to select a PCS which meets the requirement for grid connection.	☐
8.	SI and/or LEW to ensure grounding protection is provided and sufficient breaker capacity at the switch box.	☐
9.	SI and/or LEW to determine if Lightning Protection System is needed for outdoor BESS.	☐
10.	Engage a QP to ensure BESS is designed according to SCDF's requirements. The appointed QP will be responsible for the fire safety works.	☐
11.	QP to ensure the building structure or outdoor is safe for BESS deployment: i. Load bearing of the floor. ii. Fire escape route is properly planned.	☐
12.	LEW to apply Electrical Installation Licence or update single-line diagram.	☐
13.	QP to schedule a consultation with SCDF and submit Plan Approval for fire safety works.	☐
14.	SI to ensure FAT is conducted to detect any fault.	☐
15.	LEW to apply for Electricity Connection.	☐
16.	Preparation of site for the arrival of BESS equipment (e.g. battery, racks, container, PCS).	☐
17.	During assembly and installation of BESS, LEW to ensure i. System is installed by qualified installers. ii. PCS is set for anti-island mode. iii. Cables are properly connected, secured and routed.	☐
18.	Engage a RI to inspect and certify the fire safety works.	☐
19.	QP to apply for Fire Safety Certificate.	☐
20.	Apply for Electricity Generation or Wholesaler Licence where applicable.	☐

[11] Please note that the list is non-exhaustive and is subject to changes.

No.	Design and Installation Checklist	Check Box
21.	Register as MP if the BESS would be providing market services.	☐
22.	SI and/or LEW to ensure continuity and insulation tests are conducted.	☐
23.	SI to conduct SAT and compare results with the FAT results. Contact battery supplier immediately if there is any abnormal operation.	☐
24.	Completion of testing and system commissioning by SI.	☐
25.	SI to conduct system training of operators.	☐
26.	Proper system, documentation/manual handover to owners.	☐

Appendix B. Contact Information

Electricity Generation or Wholersaler Licence	**Energy Market Authority (EMA)** Economic Regulation & Licensing Department Email: ema_erl@ema.gov.sg Tel: 6835 8000
Licensed Electrical Workers (LEWs)	**Energy Market Authority (EMA)** Electricity Inspectorate Branch Email: ema_lei@ema.gov.sg Tel: 6835 8060
Connection to the Power Grid	**SP Services Ltd (SPS)** Electrical Installation Section Email: installspgroup.com.sg Tel: 6916 7200 **SP PowerGrid (SPPG)** Asset Management & Projects Department Email: DERenquiries@spgroup.com.sg Tel: 6916 8888
Fire Safety Certificate	**Singapore Civil Defence Force (SCDF)** SCDF QP Consultant Email: SCDF_CSC@scdf.gov.sg Tel: 1800-2865555
Electricity Market Rules, Market Registration Process, and Market Charges	**Energy Market Company (EMC)** Market Administration Team Email: MPregistration@emcsg.com Tel: 6779 3000

Appendix C. Examples of ESS Deployments in Singapore

Figure 9: Self-Regulating Integrated Electricity-Cooling Networks ("IE-CN") at the Marina Bay district cooling system [Courtesy of Singapore District Cooling Pte Ltd]

Awarded by EMA under the Smart Grid Grant Call II (2014), Singapore District Cooling and the Institute for Infocomm Research developed a hybrid 400 kW/400 kWh Lithium-Ion battery with Thermal Energy Storage (i.e. ice tanks). The IE-CN is able to lower the district cooling network's electricity costs of producing chilled water by up to 38% and mitigate fluctuations in electricity demand to maintain grid stability. In recognition of its outstanding R&D efforts, this project was awarded the Merit Award under the Minister for National Development's R&D Awards 2019.

Virtual Power Plant

EMA and Sembcorp awarded a grant to Nanyang Technological University to develop Singapore's first Virtual Power Plant, which looks to control and manage distributed solar photovoltaics and ESS across Singapore. Electricity produced from these energy resources at end users' premises can be coordinated intelligently like a "single utility-scale power station".

ESS Test-bed

In Oct 2017, EMA and SP Group jointly awarded Singapore's first grid-level ESS Test-bed to evaluate the performance of Lithium-Ion ESS for different grid applications under Singapore's hot, humid and urbanised environment. A 2.4 MW/2.4 MWh Lithium-Ion ESS was deployed in a substation as Singapore's first utility-scale ESS. Insights from this Test-bed helped to establish the standards and guidelines associated with the deployment of ESS, and shaped the policy and regulation framework required to facilitate the introduction of ESS into the electricity market.

Distributed ESS

Awarded under EMA's Energy Storage Grant Call in 2016, the project team, consisting of Nanyang Technological University, Panasonic and Sunseap, developed a cost-effective Distributed ESS. It connects Lithium-Ion Battery at multiple sites under a centralised control system to manage fluctuating output of IGS.

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