Technical Guidelines for Interconnection of Distributed Generator to Distribution System

2018

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Distribution Network Department

Tenaga Nasional Berhad

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Abbreviation		
AC	:	Alternating Current
AD	:	Anaerobic Digestion
AFC	:	Alkaline Fuel Cell
BMA	:	Borang Maklumat Awal
CCC	:	Connection Confirmation Check
CH_4	:	Methane Molecule
CHP	:	Combined Heat And Power
CPV	:	Concentrating Photovoltaic
CSP	:	Concentrating Solar Power
CSR	:	Codes, Standards And Regulations
CT	:	Current Transformer
DC	:	Direct Current
DFIG	:	Doubly-Fed Induction Generator
DG	:	Distributed Generator
DGPV	:	Distributed Generation Photovoltaic
DGRM	:	Distributed Generation Rotating Machine
DL	:	Distribution Licensee
EFB	:	Empty Fruit Bunch
FiAH	:	Feed-In-Approval Holder
FiT	:	Feed-In Tariff
GE	:	General Electric Company
GPS	:	Global Positioning System
IF	:	Interconnection Feeder
KeTTHA	:	Ministry Of Energy, Green Technology And Water
LSS	:	Large-Scale Solar
LV	:	Low Voltage
MBIPV	:	Malaysia Building Integrated Photovoltaic
MCFC	:	Molten Carbonate Fuel Cell
MV	:	Medium Voltage
NEDA	:	New Enhanced Dispatch Arrangement
NEM	:	Net Energy Metering
NEMAS	:	NEM Assessment Study
PAFC	:	Phosphoric Acid Fuel Cell

PCC	:	Point Of Common Coupling
PCS	:	Power Conditioning System
PE	:	Distribution Sub-Station
PMU	:	Transmission Main Intake
PMWT	:	Permanent Magnet Wind Turbine
POME	:	Palm Oil Mill Effluent
PPU	:	Main Distribution Sub-Station
PQ	:	Power Quality
PSS	:	Power System Studies
PV	:	Photovoltaic
RE	:	Renewable Energy
RPM	:	Rotations Per Minute
SEDA	:	Sustainable Energy Development Authority
SelCo	:	Self-Consumption
SESB	:	Sabah Electricity Sdn Bhd
SLD	:	Single Line Diagram
SMES	:	Superconducting Magnetic Storage Systems
SOFC	:	Solid Oxide Fuel Cell
SPP	:	Solar Power Producer
SS	:	Sewage Sludge
SSU	:	Main Switching Station
ST	:	Suruhanjaya Tenaga
T&O	:	Technical and Operation
THD	:	Total Harmonic Distortion
THDV	:	Total Harmonic Distortion Voltage
TNB	:	Tenaga Nasional Berhad
UPS	:	Uninterruptible Power Supply
VFA	:	Volatile Fatty Acid

GLOSSARY

Anaerobic Digestion (AD)	:	A collection of processes by which microorganisms break down biodegradable material in the absence of oxygen.
Breaker	:	A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by excess current, typically resulting from an overload or short circuit. Its basic function is to interrupt current flow after a fault is detected. There are two types of breaker; indoor or outdoor.
Combined Heat and Power (CHP) Cycle	:	Known as cogeneration, this cycle generates electricity and useful thermal energy in a single, integrated system.
Connection Confirmation Check (CCC)	:	Connection Confirmation Check (CCC) is an assessment to determine the optimal technically feasible method for a proposed connection of a low voltage DG installation to a utility connection point. The CCC assessment is pre-requisite for Feed-in Tariff application set by SEDA Malaysia.
Current Transformer (CT)	:	Current transformer (CT) is a type of transformer that is used to measure AC Current. It produces an alternating current (AC) in its secondary which is proportional to the AC current in its primary.
Demand	:	The demand of MW or MVAr of electricity (i.e. both Active Power and Reactive Power respectively) unless otherwise stated.
Distributed Generator (DG)	:	A generator, including a consumer with own generation, whose generating units are directly connected to the distributor's distribution system or to the distribution system of an embedded distributor which is connected to the distributor's distribution system, and not having any connection with the transmission system. DG includes energy storage system.
Distribution Sub-station (PE)	:	Distribution sub-stations (PE) are capacity injection points from 11 kV and sometimes 33 kV systems to the low voltage network (415 V, 240 V). Typical capacity ratings are 1000 kVA, 750 kVA, 500 kVA and 300 kVA.
Distribution System	:	The system of electric lines with voltage levels below 66 kV, within the Area of Supply owned or operated by the Distributor/Embedded Distributor, for distribution of electricity from Grid Supply Points or Generating Units or other entry points to the point of delivery to Customers or other Distributors and includes any electrical plant and meters owned or operated by the Distributor/ Embedded Distributor in connection with the distribution of electricity .
Distributor	:	A person who is licensed and distributes electricity for the purpose of enabling a supply to be given to any premises. "Distribute" means to operate, maintain and distribute electricity through the electricity distribution system.

Energy Storage System	:	Energy storage system is a device that stores energy to perform useful processes at a later time.
Feed-in Tariff (FiT)	:	A policy mechanism that obliges Distribution Licensees (DLs) to buy from Feed-in-Approval Holders (FiAHs) the electricity produced from grid-connected renewable energy developers over a fixed period at a particular rate, which is set by a governmental agency, Sustainable Energy Development Authority (SEDA) Malaysia.
Filter	:	A generic term used to describe those types of equipment whose purpose is to reduce the harmonic current or voltage flowing in or being impressed upon specific parts of an electrical power system, or both.
Flicker	:	Power-line flicker is a visible change in brightness of a lamp due to rapid fluctuations in the voltage of the power supply. The voltage drop is generated over the source impedance of the grid by the changing load current of an equipment or facility. These fluctuations in time generate flicker.
Harmonic	:	A sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency.
Inverter	:	A machine, device, or system that changes dc power to ac power.
Islanding	:	A condition in which a portion of the utility system that contains both load and distributed generators remains energized while isolated from the remainder of the utility system.
Large Scale Solar (LSS)	:	Any solar photovoltaic plant with minimum size of 1MWac and maximum of 50MWac, connected to either the transmission system or distribution system in Peninsular Malaysia, Sabah or Labuan.
Low Voltage (LV)	:	A voltage normally exceeding extra low voltage but not exceeding 1,000 volts alternating current or 1,500 volts direct current between conductors, or 600 volts alternating current or 900 volts direct current between conductor and earth.
Low Voltage Ride Through (LVRT)	:	Low Voltage Ride Through is the capability of electric generators to stay connected in short periods of lower electric network voltage (cf. voltage dip). It is needed at distribution level (wind parks, PV systems, distributed cogeneration, etc.) to prevent a short circuit at HV or EHV level from causing a widespread loss of generation.
Main Distribution Sub-station (PPU)	:	Main Distribution Sub-station (PPU) is normally applicable to 33 kV for interconnecting 33 kV networks with 11 kV networks. It provides capacity injection into 11 kV network through a standardized transformation of 33/11 kV.
Main Switching Station (SSU)	:	Main Switching Station (SSU) at 33 kV and 11 kV are established to serve the following function:- 1. To supply a dedicated bulk consumer (33 kV and 11 kV) 2. To provide bulk capacity injection or transfer from a PMU/PPU to a load center for further localized distribution.

Medium Voltage (MV)	:	A voltage normally exceeding low voltage but equal to or not exceeding 50 000 volts.
Net Energy Metering (NEM)	:	A mechanism where an eligible consumer installs a solar PV system primarily for his own use and the excess energy to be exported to the grid for which credit to be received that may be used to offset part of the electricity bill for energy provided by the distribution licensee to the electricity consumer during the applicable billing period.
NEM Assessment Study (NEMAS)	:	A pre-requisite study for NEM application and shall be performed prior to the approval of the NEM application. The study shall be conducted by DL to establish the technical and safety requirements and determine the feasibility of interconnection.
Nominal	:	The value or range of a parameter being within expected norms or being the normal operating level of that parameter.
Nonlinear Load	:	A load that draws a non-sinusoidal current wave when supplied by a sinusoidal voltage source.
Palm Oil Mill Effluent (POME)	:	Waste water discharged from the sterilization process, crude oil clarification process and cracked mixture separation process.
Power System Study (PSS)	:	Studies to analyze and improve electrical system safety, reliability and efficiency. Power system studies are performed for new systems during the design phase, after modifications to the feeding power grid, and before modifications to existing electrical systems.
Point Of Common Coupling (PCC)	:	The point on the distribution system, electrically closest to the user's connection point, at which other users supplies are connected.
Power Factor	:	Power factor (PF) is calculated by dividing the Real Power, P, in the W unit by the Apparent Power, S, in the VA unit. $$PF = \frac{Real\ power,\ P\ (W)}{Apparent\ power,\ S\ (VA)}$$ Where S is the square root of the sum of the squares of real power and reactive power, Q (unit: Var). $$S = \sqrt{P^2 + Q^2}$$
Relay	:	A relay is an electrically operated switch. Protective relay is a relay device designed to trip a circuit breaker when a fault is detected.
Renewable Energy Fund	:	Financing for the FiT mechanism, established under Section 23 of the RE Act 2011 and is contributed through collection from the total electricity bill invoiced by distributors such as Tenaga Nasional Berhad (TNB) or Sabah Electricity Sdn Bhd (SESB).
Safety Codes,	:	Codes, standards, and regulations are developed, maintained, and

Standards and Regulations (CSR)		promoted by regulatory agencies, engineering societies, trade organizations, and private companies. Engineering codes, standards, and regulations all serve to ensure the quality and safety of equipment, materials, and processes.
SCADA	:	Supervisory control and data acquisition (SCADA) is a control system architecture that uses computers, networked data communications and graphical user interfaces for high-level process supervisory management, but uses other peripheral devices such as programmable logic controllers and discrete PID controllers to interface to the process plant or machinery.
Sewage Sludge	:	Residual, semi-solid material that is produced as a by-product during sewage treatment of industrial or municipal wastewater.
TNB	:	Tenaga Nasional Berhad is a Licensee that was issued a Licence on 1st September 1990 which authorizes TNB to own and operate electricity generating, transmitting and distributing facilities and to supply energy to other persons therefrom.
Transmission Main Intake (PMU)	:	Transmission Main Intake (PMU) is the interconnection point of 132 kV or 275 kV to the distribution system.
Total Harmonic Distortion (THD)	:	Harmonic distortion is the departure of a waveform from sinusoidal shape that is caused by the addition of one or more harmonics to the fundamental. Total Harmonic Distortion is the square root of the sum of the squares of all harmonics expressed as a percentage of the magnitude of the fundamental.
Type Test	:	Test of one or more devices made to a certain design to demonstrate that the design meets certain specifications.
Voltage Transformer (VT)	:	Potential transformer or voltage transformer gets used in electrical power system for stepping down the system voltage to a safe value which can be fed to low ratings meters and relays.

Summary of the Guidebook

Chapter 1: Background & Objectives

- Introduction and objectives of DG guidelines

Chapter 2: Distributed Generation Technologies

- Introduction of DG policies and technologies in Malaysia

Chapter 3: DG Interconnection & Penetration Limit

- DG penetration and connection scheme

Chapter 4: Power Quality

- Power quality of DG interconnection, including large scale solar, wind and energy storage

Chapter 5: Protection

- Protection scheme for LV & MV DG connection, including energy storage

Chapter 6: SCADA

- SCADA and automation

Chapter 7: Metering

- Direct & indirect connection, meter application, approval and reading

Chapter 8: Safety

- DG safety, safety documentation and incident preparedness

Chapter 9: Application Process

- Detailed procedure on application of DG, information required and submission

Chapter 10: Testing & Commissioning

- DG testing, IOM, PQ measurement, commissioning test, anti-islanding test and reliability run

Chapter 11: Interconnection Operation Manual

- Interconnection facilities, communication, switching procedures, fault reporting, outage program,sequence of operation and safety requirement

1.0 BACKGROUND & OBJECTIVES

In 2009, the National Renewable Energy Policy and Action Plan was introduced to enhance the utilisation of indigenous Renewable Energy (RE) resources to contribute towards national electricity supply security and sustainable socioeconomic development. The objectives are as follows:

- To increase RE contribution in the national power generation mix;
- To facilitate the growth of the RE industry;
- To ensure reasonable RE generation costs;
- To conserve the environment for future generations; and
- To enhance awareness on the role and importance of RE.

Additionally, the parliamentary approval of the Renewable Energy Act in 2011 acted as a catalyst for the implementation of a special tariff system for renewable energy generation and ensured the entrance of privately operated renewable generation into Malaysia's electricity grid. The large amounts of applicants and future operators of renewable generators has led to the need for a set of unifying rules to allow for a smooth transition into implementation of renewable generation on the grid. Hence, the need for this guidelines.

The scope of this guidelines covers Distributed Generator (DG) such as but not limited to solar PV, biomass, biogas, small hydro, energy storage systems and wind turbines in the following current schemes: Feed-in-Tariff (FiT), Large Scale Solar (LSS), Net Energy Metering (NEM), Self-Consumption, Co-Gen, New Enhanced Dispatch Arrangement (NEDA).

This document is focused on providing recommended practice for utility interconnection of DG systems in a manner that will allow the DG systems to perform as expected and be installed at a reasonable cost while not compromising safety or operational issues.

2.0 DISTRIBUTED GENERATION TECHNOLOGIES

2.1 POLICIES

In 2011, Malaysia introduced the Renewable Energy Act 2011 (Act 725) for the establishment and implementation of a special tariff system to catalyse the generation of renewable energy. The following are the various schemes introduced by the government.

2.1.1 FEED-IN TARIFF (FiT)

The Feed-in Tariff (FiT) scheme was introduced in Malaysia in 2011 [1]. The Feed-in Tariff (FiT) system in Malaysia requires the Distribution Licensees (DLs) to purchase from Feed-in Approval Holders (FIAHs) the electricity produced from renewable resources (renewable energy) [2].

The DLs are the companies licensed to distribute electricity such as TNB and SESB. Fixed premium rate is payable for each unit of renewable energy sold to Distribution Licensees. The FiT rate differs for different renewable resources and installed capacities. Bonus FiT rate applies when the criteria for bonus conditions are met. The DLs will pay for renewable energy provided to the electricity grid for a specific duration. The duration is the period of which the renewable electricity could be sold to distribution licensees and paid with the FiT rate. The duration is based on the characteristics of the renewable resources and technologies. The duration is 16 years for biomass and biogas resources, and 21 years for small hydropower and solar photovoltaic technologies [2].

Financing for the FiT mechanism is sourced from the Renewable Energy (RE) Fund. This fund is established under Section 23 of the RE Act 2011 and is contributed through the collection of an additional surcharge from the total electricity bill invoiced by DLs. However, domestic consumers who use less than a predetermined electricity per month are exempted from contributing to the RE Fund.

2.1.2 NET ENERGY METERING (NEM)

The Net Energy Metering (NEM) is a mechanism where a qualified consumer installs a solar PV system primarily for his own use. The extra energy to be transferred to the grid for which credit to be received may be used to offset part of the electricity bill, for energy provided by the DL to the electricity consumer during the applicable billing period [3, 4].

The concept of NEM is that the energy produced from the solar PV system installed will be consumed first, and any excess to be transferred and sold to the DL at the prevailing Displaced Cost prescribed by the Energy Commission. This scheme is applicable to all domestic, commercial and industrial sectors as long as they are the customers of TNB (Peninsular Malaysia) or SESB (Sabah and FT Labuan). The PV systems are permitted to be installed at available rooftops or car porch only within their own premise. Based on FiT experience, solar PV is a technology that requires least construction and with high take up rate compared to other DG technologies. One factor driving such growth is the decreasing cost of solar PV systems in recent years. As solar PV technology is more applicable to the NEM, it is the only technology whereby the public at large can play their role in addressing climate change by generating the clean energy, hence diminish the energy consumption from electricity generated by fossil fuel powered generators [5].

NEM scheme is ideally suitable to complement the current FiT and Large Scale Solar (LSS) programmes. The NEM scheme is widely implemented globally and can further contribute in accomplishing the national DG target, and decrease dependency on imported fossil fuels. Malaysia will be executing its 500MW capacity under the Net Energy Metering (NEM) programme beginning 1st November 2016 until 2020 with 100MW capacity limit a year in Peninsular Malaysia and Sabah

[6]. NEM is executed by the Ministry of Energy, Green Technology & Water, regulated by the Energy Commission (EC), with Sustainable Energy Development Authority (SEDA) Malaysia as the implementing agency [5].

2.1.3 LARGE-SCALE SOLAR (LSS)

Large-Scale Solar (LSS) refers to any solar photovoltaic plant with minimum size of 1MWac and maximum of 50 MWac, connected to either the transmission system or distribution system in Peninsular Malaysia, Sabah or Labuan. The implementation of the LSS began in the year 2016. The difference between LSS and distributed generation is the scale of the plant/project/facility and that the generated electricity is sold to wholesale utility buyers, not end-use consumers. The target capacity for the LSS program is 1000 MWac by 2020 with annual capacity capped at 200 MWac for Peninsular and 50 MWac for Sabah for 2017, 2018, 2019 and 2020 [7].

The implementation mechanism for selection of potential developers under the LSS programme shall be through a Competitive Bidding framework, unless otherwise directed by the Minister. The yearly target capacity cap may be reviewed periodically by the Energy Commission based on the achievement of the overall off take of the capacity open for bidding, and the progress of the projects implemented by the successful bidders [7].

2.1.4 NEW ENHANCED DISPATCH ARRANGEMENT (NEDA)

The New Enhanced Dispatch Arrangement (NEDA) is for the scheduling and dispatch of generation to enhance short-run competition and improve cost efficiency of generation. The NEDA rule sets out the principles and prescribe the guidelines on the operation and the roles, functions, obligations and rights of the Single Buyer, the Grid System Operator, the Grid Owner, the Distributors and the NEDA Participants on NEDA, as amended from time to time. The NEDA agreement which is an agreement(s) between a NEDA Participant (PPA/SLA Generators and Merchant Generators) and the Single Buyer or the Grid Owner or a Distributor, whichever relevant, whereby the NEDA Rules are given contractual effect and made binding between the relevant parties [8]. NEDA began commencing since October 2015 with the hope of helping to push down the cost of electricity tariffs in Malaysia [9].

NEDA was formulated to develop competition and cost efficiency of the Single Buyer market with the following objectives:

a. to improve cost efficiency in generation through short-run competition
b. to enable energy-efficient options, mainly the use of efficient technology, such as cogeneration, to join in the electricity market
c. to provide opportunity for non-PPA/SLA generators, such as co-generators, franchise utilities with generation facilities, Ex-PPA/SLA generators and other generators which manage their own fuel requirements and with the consent of the Energy Commission to operate as merchant generators to supply and sell energy to the Single Buyer to improve their business options by taking full advantage of the use of their facilities in a cost-efficient manner for the advantage of the electricity supply industry and the consumers.

2.1.5 SELF-CONSUMPTION

Self-Consumption refers to customers with own generation with installed capacity only for self-consumption. In the event of extra energy generation, the energy is not to be exported to the grid. As no export of power is permitted, therefore self-consumption consumer shall install a device that will prevent the export of power to the grid. The export curtailment is to prevent any voltage increase at the point where the indirect Solar PV power generation system is connected to the consumer MSB [10].

2.1.6 CO-GENERATION

Co-Generation Plant is a Generation Facility where a single fuel source is used for the instantaneous production of thermal energy and electrical or mechanical energy. With the NEDA implementation, it enables energy-efficient options, particularly the use of efficient technology, such as co-generation, to partake in the electricity market.

2.2 TECHNOLOGIES

2.2.1 SOLAR

Solar PV panels are available in many forms, particularly monocrystalline, polycrystalline, and thin-film types. The PV panels output electrical energy converted from sunlight to an inverter, which then convert the DC voltage into an AC sine wave. Inverters depend on power electronic components like the Insulated Gate Bipolar Transistor (IGBT) to perform its duties. At the point of common coupling (PCC), a dedicated transformer is used to step the voltage up to the appropriate level. When connected to the grid, a PV system can function as a DG that assists the main generation systems by supplying power into the grid. Large-scale PV systems are made up of a number of arrays that produce reasonably high amounts of power during day time periods [11].

Due to the modular nature of PV, the construction of a large scale PV plant is only a matter of scale, with higher numbers of panels connected in strings and in parallel which is connected to a number of inverters according to the required capacity. This is due to when more solar panels are connected in series, the output voltage of the string rises. Thus, the number of panels required for a certain voltage level, such as 415 V, is calculated by dividing the required voltage with the voltage output of one panel. These strings are consequently connected to the inverters in parallel to achieve the desired peak output power, expressed in MWp. Inverter configurations are normally in two modes, string and central.

Central inverter designs depend on a single inverter unit that receives DC outputs from multiple PV panel strings connected in parallel [12]. To accommodate for the different levels of solar radiation throughout the day, a single inverter is divided into multiple output units. For a 2 MW central inverter, it can be composed of four 500 kW output units, configured in a master/slave system. In this way, one output unit is designated the master, while the rest operate as slaves. The slaves will be activated according to the output power of the solar array at any given time. To prevent excessive wear and tear, the master role is cycled among the output units in turns to balance out the operating times of each unit.

String inverters have smaller capacities compared to central inverters, due to the fact that each can handle only a string of PV panels. For PV plants equipped with tracking systems, string inverters are a better choice. This allows separation of tracker control for each string, thus increasing the effectiveness of the entire PV plant. The panels can track the sun more precisely relative to their ground location.

It must be noted that, especially for large-scale PV, caution needs to be taken as to its effect on the distribution system it is connected to. With higher penetration of PV, meaning a higher ratio of PV power injection compared to loading, significant grid stability issues may arise. Grid voltage fluctuation is an important concern. Traditional networks are theorized as systems with large generators connected away from the load side, so power transfer occurs from the higher voltage level to the point of consumption at lower voltage levels. With a DG source such as PV connected near loads, there can be a significant difference in power flow.

PV is an intermittent energy source; therefore there can be high amounts of power injection during periods of high solar radiation, even though the demand is at low levels, for example during mornings where there is fewer activity in households. This can cause an unwanted overvoltage condition. Overvoltages are not a rare incidence, and there are measures in distribution systems to compensate for them, such as on-load tap changers. Still, PV constitutes an extra burden to the voltage control system already in place. These issues can be controlled in the presence of regulatory standards that are closely adhered to by all PV operators.

2.2.2 BIOGAS

Since the 1970s, biogas production through the process of anaerobic digestion (AD) has been the focus of global research. This prevailing technology has the capability of converting organic material into useful energy in the form of biogas. Previously, AD was mainly used for waste water sludge stabilization, but it is now being adopted for other waste management sectors.

Anaerobic Digestion

During the AD process, organic biodegradable material is broken down by microorganisms in the absence of oxygen. It breakdown occurs in 4 stages, namely hydrolysis, acidogenesis, acetogenesis and methanogenesis. During hydrolysis, insoluble organic material such as complex proteins, fats and carbohydrates into its backbone constituents, which are amino acids, fatty acids and simple sugars [13].

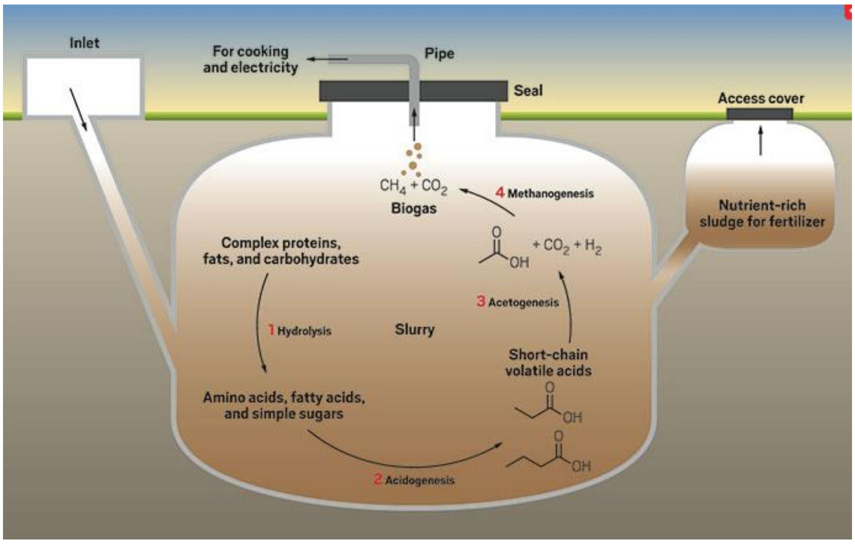


Fig. 2.1 A simple anaerobic digester where different bacteria break down the waste that is loaded inside in four stages [13].

The second stage is acidogenesis, whereby the components formed during hydrolysis are further simplified into hydrogen, carbon dioxide, acetates (a salt or ester of acetic acid), and volatile fatty acid (VFA). Acidogenic bacteria assist this stage and the products are converted into consumables for the methanogens. In the third stage, which is acetogenesis, VFAs are digested to produce acetate and hydrogen [14]. It is to be noted that partial pressure of hydrogen in the substrate tremendously influences this conversion.

Finally, the acetate and some of these gaseous compounds are consumed by methanogenic bacteria, which use the building blocks to produce methane. Throughout the process, some carbon dioxide and hydrogen sulphide are released with the methane, making up the components of raw biogas. The different types of bacteria participating in various stages of AD each have its own optimum pH to ensure efficient digestion and gas production [14].

Biogas to electricity technologies

The theory behind it is that the chemical energy of the combustible gases is converted to mechanical energy in a controlled combustion system by a heat engine. This mechanical energy then activates a generator to produce electrical power. The most common heat engines used in for biogas energy conversion are gas turbines and combustion engines.

In most cases, biogas is used as fuel for combustion engines, which convert it to mechanical energy, powering an electric generator to produce electricity. The design of an electric generator is similar to the design of an electric motor. Most generators produce alternating AC electricity; they are therefore also called alternators or dynamos. Appropriate electric generators are available in virtually all countries and in all sizes. The technology is well known and maintenance is simple.

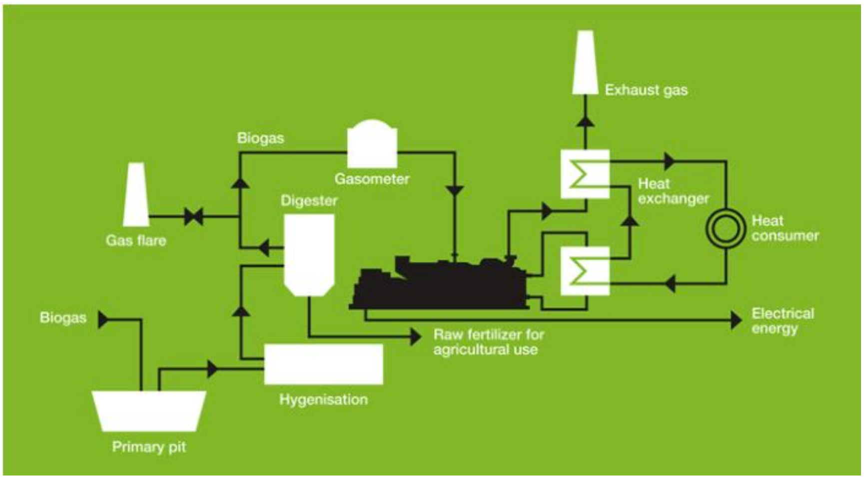


Fig. 2.2 Biogas cogeneration flow diagram.

Biogas systems are an environmental friendly way to generate energy and have a positive impact on climate change. In fact, the contribution of a methane molecule (CH_4) to the greenhouse effect is 21 times greater than that of a carbon dioxide molecule. Therefore burning methane, despite producing CO_2, reduces its impact on the environment. In Malaysia, common feedstock for ADs include palm oil mill effluent (POME), sewage sludge (SS), landfill waste, animal manure, diary manure and food waste.

2.2.3 BIOMASS

Biomass is organic matter, which through the process of combustion, can be transformed to useable energy. It comprises of all living matter available on earth, including algae, trees, crops and animal manure. Biomass resources generally comprise of carbon, hydrogen, oxygen and nitrogen, along with minor amounts of sulphur. Through the process of photosynthesis, plants produce carbohydrates, which are the basic component of biomass.

Uses of biomass

Biomass is used to meet a variety of energy needs, such as generating electricity, fuelling vehicles, providing process heat for industries and feedstock for chemicals. Currently, it provides 10 - 14 % of the world's energy supplies. In nature, if biomass is left lying around on the ground it will break down over a long period of time, releasing carbon dioxide and its store of energy slowly. By burning biomass, its store of energy is released quickly and often in a useful way. So, converting biomass into useful energy imitates the natural processes but at a faster rate [15].

Biomass Feedstock

Sources of biomass can be primarily divided into three major categories, namely wastes, standing forests, and energy crops. Waste products that can be considered as biomass are agricultural wastes, agro-industrial process waste, crop residues, etc. Standing forests wastes are made up of a variety of intermediate products and residual wastes of different nature.

Energy crops include diversified edible and non-edible crops. Biomass resources used for energy production can be classified as modern biomass and traditional biomass. Modern biomass is involved in large-scale uses and is meant as a substitute for conventional energy sources. This includes agricultural and forest residues and solid waste. On the other hand, usage of traditional biomass, such as fuelwood is limited to developing countries and small-scale usage [15].

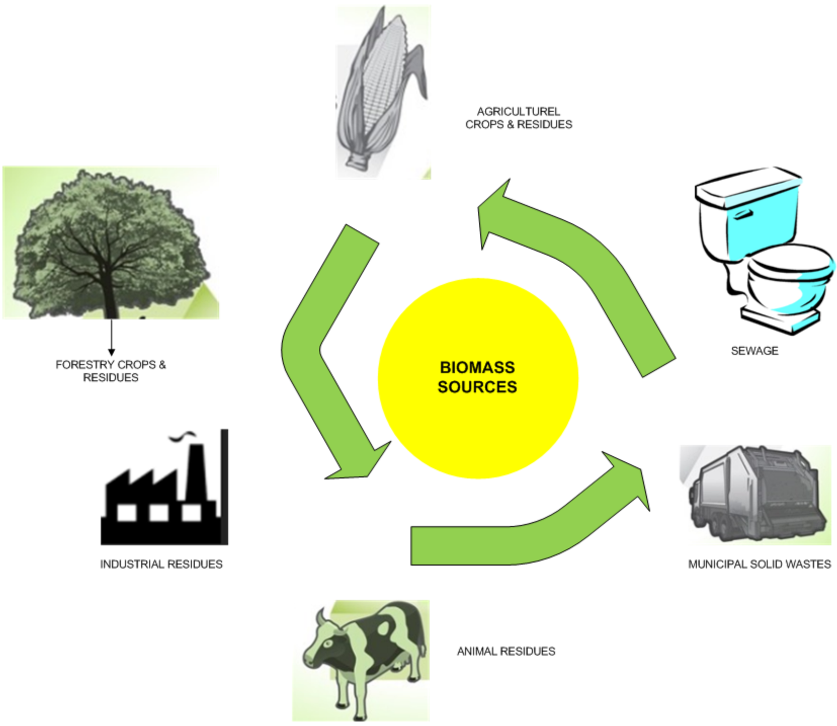


Fig. 2.3 Various biomass sources.

Biomass to energy systems

Energy is obtained using biomass in numerous ways. Nearly all of the biomass energy is utilized for domestic purposes and by wood-related industries. It can be directly combusted to produce steam that drives a turbine/generator to generate electricity. Gasifiers are used to transform biomass into a combustible gas, which can drive a high efficiency, combined cycle gas turbine. Heating biomass produces pyrolysis oil (similar like petroleum), which can be burned to produce electricity. Pyrolysis oil has the advantages of easier storage and transportation compared to solid biomass material [16].

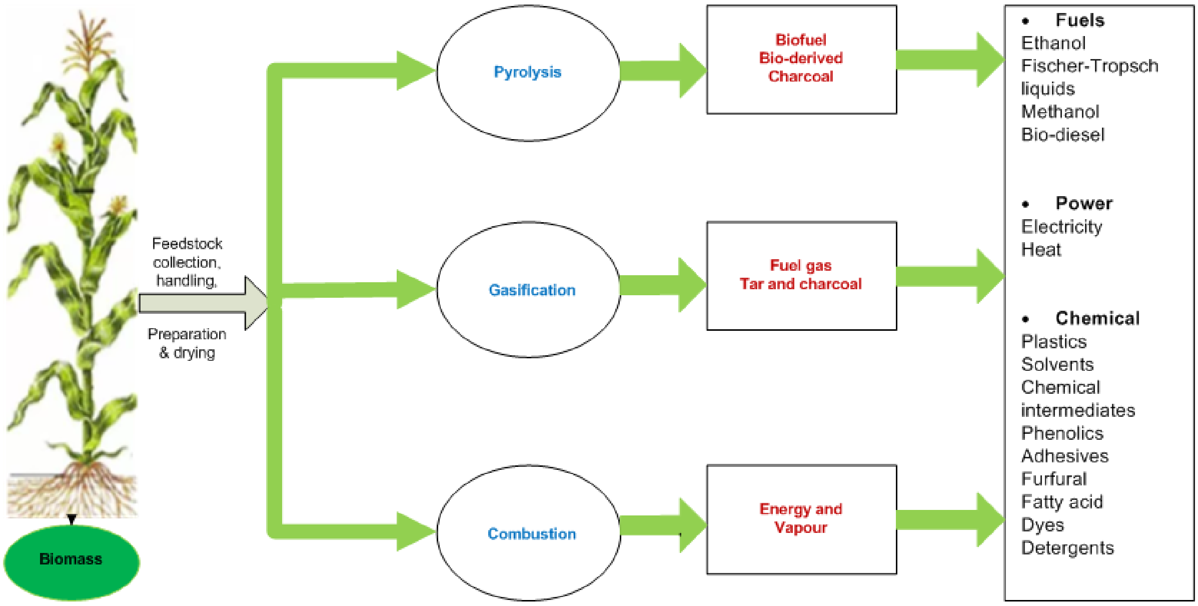


Fig. 2.4 Thermochemical Conversion Technologies for Biomass.

2.2.4 HYDROPOWER

Water is one of the most commonly-used sources of power generation as it is cheap and readily-available. A hydropower plant converts the energy of falling water into electricity. Dams are built across rivers to elevate water levels to contribute the drop necessary to provide driving force as the potential energy in the water is directly proportional to the head (difference in height between source and outlet). There are also run-of-river facilities that do not rely on dams. Typically a run-of-river project will have little or no storage facility. Run-of-river contributes a consistent supply of electricity (base load), with some flexibility of operation for daily fluctuations in demand through water flow that is controlled by the facility.

Water in the reservoir flows into the intake and passes through a pipe called the penstock. The highly-pressurized flow of the water turns the blades of the turbine. The turbine powers a generator, which converts mechanical energy into electrical energy. The electricity is then stepped up by a transformer to the nominal voltage before transmission to the National Grid.

The scale of a hydropower range in size from large power plants that supply many consumers with electricity up to small and micro plants that individuals operate for their own energy needs or to sell power to utilities. In Malaysia, only hydro plants below 30MW are eligible for RE funding mechanisms as discussed in sub-section 2.1. As the size is small, many of the small hydro installations are run-of-river type [17].

2.2.5 WIND

Wind energy is formed due to the Sun's unbalanced heating of the atmosphere, uneven surface of the Earth's topography and the planet's orbit around the Sun. Apart from generating electricity; wind energy is also useful for charging energy storage devices, as well as traditional purposes such as grinding grain and pumping water. Generally wind energy technologies are used as stand-alone applications or as hybrid systems integrated with photovoltaic systems and then connected to a power grid.

For wind sources with large megawatt capacities, many turbines are built adjacently and interconnected to form wind farms that can supply power to the national power grid. In windy areas, home and farm owners also use small wind systems to produce power for their own use. Stand-alone turbines can also be used for water pumping or communications. Latest wind turbine models have larger blades, enabling greater wind utilization, thus produces more electricity, making renewable energy generation cost-effective.

Wind Technology Mechanism

The operating principle of a wind turbine is relatively simple. The wind turns the blades causing a turning force. The rotating blades turn a shaft inside the nacelle, which goes into a gearbox. The rotational speed and subsequently energy of the generator is increased by the gearbox. The generator uses magnetic fields to transform rotational energy into electrical energy at about 700V. The produced power output enters a transformer that will function to step-up this current to a higher voltage for the distribution system (usually between 11 kV and 132 kV) before grid injection. The two commonly used technologies are permanent magnet wind turbine (PMWT) and doubly-fed induction generator (DFIG) wind turbine.

2.2.6 COGENERATION

Cogeneration, or combined heat and power (CHP), is an exceptionally efficient form of power generation that simultaneously produces electricity and heat. The exhaust energy from heat engines can be utilized to generate additional energy, usually in the form of steam in the heat exchanger, which is then used for various applications. The total efficiency of cogeneration can surpass 80 %, which is much more energy-efficient than the separate generation of electricity and useful heat [18].

The primary power source is usually any type of prime mover driven power, such as pumps, air compressors, electrical generation systems, blowers, desalinization units or centrifugal (absorption) chillers. Heat is usually recovered from the prime mover as hot water or steam. The prime mover process becomes a cogeneration system when the heat ejected from the prime mover, which is normally wasted, is recovered and is used in a heat consuming device. The primary difference between a turbine engine and a reciprocating engine is the way the heat is ejected.

Various cogeneration systems can be altered to meet the specifications of a plant or facility. The systems design is altered on the basis of size, energy requirements of the site and location. Most cogeneration systems are commonly used in applications which need continuous heating and are designed to meet the heat demand of the energy user since this will result in systems with maximum efficiency. Larger facilities typically use customized systems, while smaller-scale applications can utilize pre-packaged units.

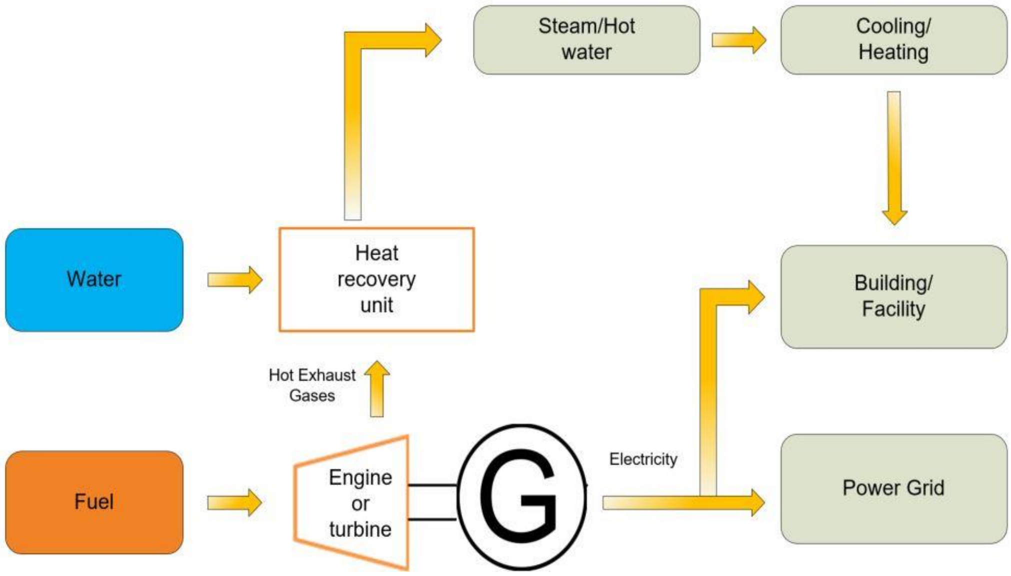


Fig. 2.5 Schematic of Combined Heat and Power (CHP) plant.

Table 2.1 Advantages and Disadvantages of Cogeneration.

Advantages	Disadvantages
• Increased efficiency in terms of energy and money savings • Enhanced reliability- system is grid independent and hence immune to grid-level blackouts • Reduces air pollutants such as SO_2, NO_X, Mercury	• Intensive capital demand • Heating and electricity demand must remain fairly consistent • Not an actual energy source, only a method of extending energy

Types of Cogeneration Plants [19]

- Gas Engine Systems: In this plant, a gas engine is used and it has higher power generation efficiency as it has two sources for heat recovery which are the high temperature exhaust gas as well as the low temperature engine jacket cooling water. Commonly used fuels include propane or natural gas. These plants are widely used in facilities which have a greater need for electricity than thermal energy and also in places that do not require high quality of heat.

- Gas Turbine Systems: These plants generate waste heat in the turbine flue gas (exhaust gas) at high temperatures, allowing greater heat recovery. It is usually powered by natural gas, sometimes by light fuel oil or diesel. Gas turbine cogeneration facilities are large in size and stored in restricted enclosures with connection to a gas line. Advantages of such system are minimal start-up time and large reduction in installation costs.

- Combined Cycle Systems: The operating principle of this kind of plant is that exhaust from one heat engine drives the other engine to produce electricity or propel mechanical processes. Multiple thermodynamic cycles are combined, working concurrently for increased efficiency and reduced fuel costs. However, the disadvantage of this technology is that most cogeneration require modification to its existing systems prior its implementation.

- Biofuel systems: Based on the composition of the biofuel used, these systems use a diesel or reciprocating gas engine, similar to a gas engine plant. Biofuel systems provide the benefits of lower hydrocarbon fuel consumption and reduced carbon emission. On the other hand, the production output of biofuel facilities is relatively meagre.

2.2.7 ENERGY STORAGE [20]

In the electric power sector, the electricity demand fluctuates throughout the day. Previously, without energy storage technologies, electricity cannot be stored. Therefore, extensive planning is required to meet the fluctuating demand in a cost-effective manner. Even then, if there were sudden changes in the system, the system operator has a very short time span and limited resources with which to respond.

Hence, there is a need for energy storage technologies, which are cost-effective, easily scalable, flexible and of long duration. Energy storage systems are being developed using various approaches. The current commercially available energy storage technologies are solid-state batteries, flow batteries, flywheels, and compressed air energy storage, thermal and pumped hydro power. The benefits of energy storage are numerous, the key benefits or applications are listed below [21] :

- Frequency regulation: Energy storage can be charged and discharged in response to changes in the grid frequency, thus addressing sudden misalignment of energy supply and demand
- Spinning reserve: Energy storage can be charged to a certain level of charge to respond to sudden system outages
- Load levelling: Energy storage can be used to store power during periods of light system load and discharge when there is high demand. This is especially useful in a system with intermittent renewable resources
- Peak shaving is similar to load levelling, but these energy storage systems are usually owned by consumers for demand side management
- Power quality : Energy storage system can provide instantaneous voltage support by injecting or absorbing, both active and reactive power

Electrical energy (in the form of electricity) is a flow, so it must be transformed to a storable form as potential, chemical, kinetic, or thermal energy. For instance, when a battery is charged, electricity is converted to chemical energy, and then returned to electrical energy when the battery is discharged. Storage technologies are classified in several categories, namely mechanical, electrochemical (and chemical), thermal, as well as electrical and magnetic energy storage, based on the type of stored energy as seen in the flow chart below.

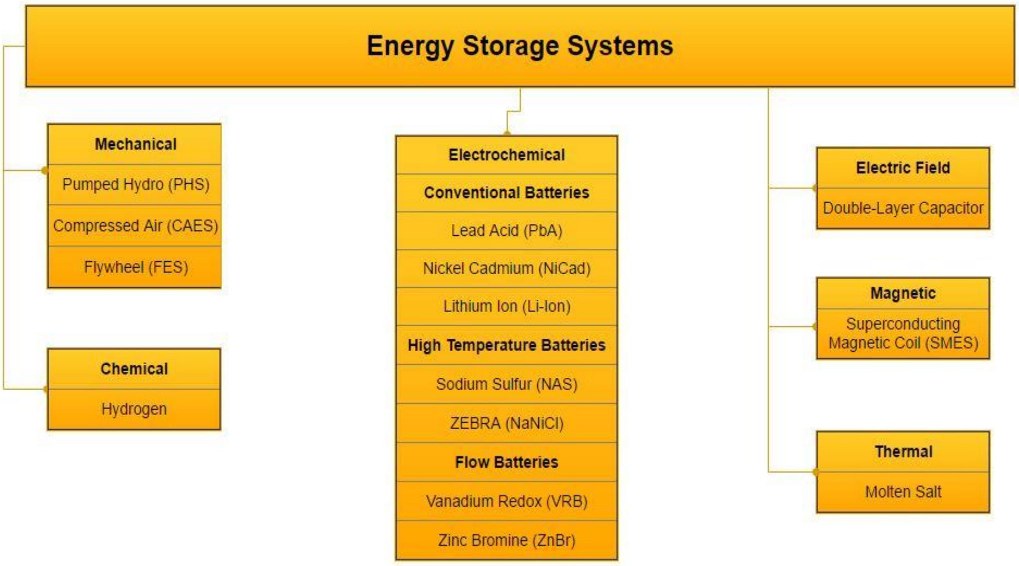


Fig. 2.6 Classifications of energy storage systems.

Flywheel Energy Storage Systems

Flywheel systems store electrical energy input as kinetic energy. The kinetic energy in this system comes from the motion of a spinning mass, which is the rotor, spinning in a practically frictionless enclosure. When utility power is inconsistent or completely lost, the inertia of the spinning body ensures continuous spinning, resulting in kinetic energy. The production of kinetic energy provides short-term back up power [22, 23].

Modern-day high-speed flywheel systems are made up of a massive rotating cylinder, which is a rim connected to a shaft that is held up on a stator by magnetically suspended bearings. The flywheel energy storage system is best operated in a vacuum to reduce drag, resulting in high efficiency. The flywheel is connected to a motor-generator and interacts with the utility grid through advanced power electronics.

Major advantages of flywheel systems are that it can bridge the gap between short-term ride-through power and long-term energy storage with outstanding cyclic and load following characteristics and have minimal environmental impact. Additionally, it has a long life-span capable of prolonged usage (some flywheels are capable of more than 100,000 full depth of discharge cycles and latest designs are capable of more than 175,000 full depth of discharge cycles) and are of low maintenance [23].

The number of rotations per minute (RPM) is directly proportional to the amount of energy stored in the flywheel, making higher rotational speeds an advantage. Current applications of high-power flywheels are aerospace and uninterruptible power supply (UPS) systems, with 2 kW or 6 kWh systems used in telecommunications applications. A 'flywheel farm' approach can be used for utility-scale storage to reserve megawatts of electricity for operations that require only minutes of discharge duration.

Table 2.2 Pros and Cons of Flywheel Storage.

Advantages	Disadvantages
• Low maintenance and long lifespan: up to 20 years • Almost no carbon emissions • Fast response times • No toxic components	• High acquisition costs • Low storage capacity • High self-discharge (3 –20 % per hour)

Batteries

A battery is a device consisting of one or more electrochemical cells that convert stored chemical energy into electrical energy. Each cell contains a positive terminal, or cathode, and a negative terminal known as the anode. Electrolytes allow ions to move between the electrodes and terminals, which allows current to flow out of the battery to perform work. The negative electrode supplies a current of electrons that flow through the appliance and are accepted by the positive electrode [22].

However, only rechargeable batteries are pertinent and will be relevant for the use of storing energy produced by renewable energy sources. Breakthroughs in material and technology have tremendously improved the reliability and output of modern battery systems, and economies of scale have drastically reduced the associated cost. Further innovation has created new inventions such as electrochemical capacitors that can be charged and discharged simultaneously and instantly, and provide an almost unlimited operational lifespan.

Table 2.3 Pros and Cons of Batteries as Energy Storage.

Advantages	Disadvantages
• Easy and therefore cheap to produce • Mature technology, more than 150 years of experience and development • Very high surge-to-weight-ratio; capable of delivering a high jolt of electricity at once, which is why they are so suitable as car starters • Easily recyclable	• Very heavy and bulky • Rather short lived • Environmental concerns: although pretty safe, lead is very toxic and exposure can cause severe damage to people and animals • Corrosion caused by the chemical reactions

Superconducting Magnetic Storage Systems (SMES)

The system comprises of three vital components, namely the coil, cooling system and the power conditioning system (PCS). The PCS is the interface between the SMES coil and the power system. Its task is to convert alternating current (AC) into direct current (DC) and vice versa since the coil is only capable of storing and releasing the energy in the form of DC. The main concept for this is the storage of energy in an electromagnetic field surrounding the coil, which is made of a superconductor [23].

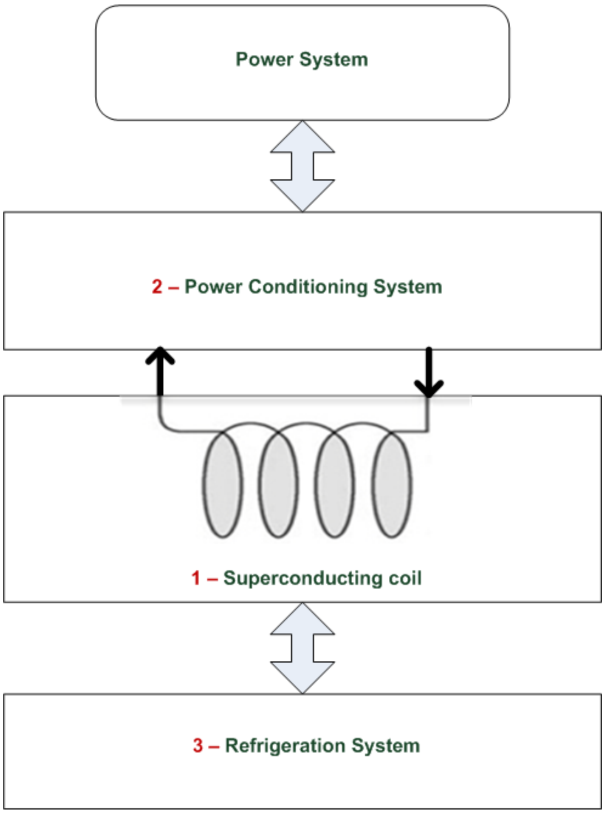


Fig. 2.7 Superconducting Magnetic Storage Systems' Components.

The primary advantage of SMES systems is that it has permanent storage, implying that stored energy may be retained indefinitely as there are no standby losses. SMES do not have common channels of energy loss such as friction, heat dissipation, evaporation and others. SMES have ability to respond instantaneously, depending solely on the solid state materials capability to react during a charge or discharge cycle.

On the other hand, since SMES are constructed from superconducting materials (e.g. niobium-titanium, niobium-tin) that can only function at temperatures below 253° C, a cooling system for these components is necessary. This can be done by liquefying helium; but, it is very costly and reduces the efficiency of the system, particularly in stand-by mode. Furthermore, production processes for these materials make them very brittle as well as tedious and expensive to fabricate [23].

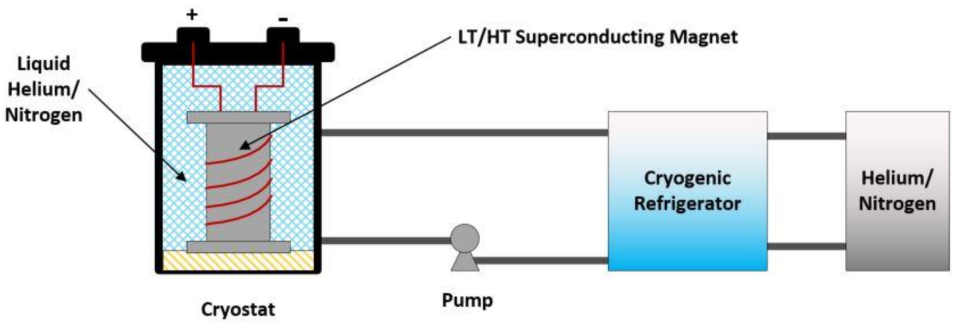


Fig. 2.8 Schematic diagram of SMES [23].

Table 2.4 Pros and Cons of SMES.

Advantages	Disadvantages
• Fast response times • Capable of partial and deep discharges • No environmental hazard	• High energy losses (~12 % per day) • Very expensive in production and maintenance • Reduced efficiency due to the required cooling process

Fuel Cells

A fuel cell is a device that creates power via an electrochemical reaction instead of combustion. It is similar to a battery, but it is able to supply energy continuously. Fuel cells can cater for energy storage systems for intermittent renewable energy sources like solar and wind.

In a fuel cell, the part that contains the fuel is the anode, and the side that encloses oxygen is the cathode. At the anode, the fuel is oxidized and produces electrons. The electrons then pass through an external circuit, extracting them from the system. At the cathode, addition of these electrons causes oxygen reduction [24]. An electrolyte barrier that allows only ions (not electrons) to pass partitions the two reactants.

When used reversibly, fuel cells provide energy storage apart from primary power generation. Excess electricity is used to electrolyze water and/or carbon dioxide to produce fuel for later usage. This excess electricity can come from a renewable source, such as wind or solar, or it can be excess grid electricity during off-peak hours. There are several types of fuel cells, distinguished by factors such as its electrolyte, specific fuel requirement, operating temperature, design and application. Examples are Alkaline Fuel Cell (AFC), Phosphoric Acid Fuel Cell (PAFC), Molten Carbonate Fuel Cell (MCFC), and Solid Oxide Fuel Cell (SOFC).

Solid oxide fuel cells (SOFCs) are a highly efficient fuel cell that uses a solid ceramic electrolyte. It can withstand high operating temperatures, thus it’s advantageous for combined heat and power generation. SOFCs fuel is usually a mixture of hydrogen and carbon monoxide, which both can be self-produced within the fuel cell from natural gas and water. Thus, expensive external fuel reformers are not needed. Furthermore, SOFCs energy storage systems can serve as the catalyst to replace fossil fuels with alternative energy sources because SOFCs are able to transmit similar energy load with financial competitiveness.

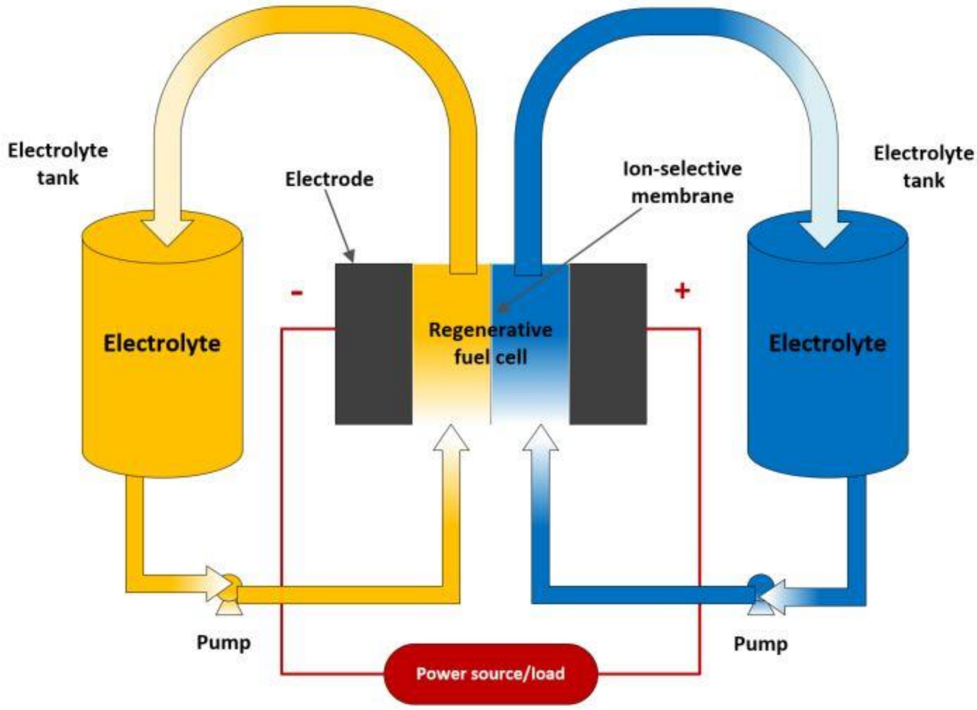


Fig. 2.9 Fuel cell design.

Table 2.5 Pros and Cons of Fuel Cells.

Advantages	Disadvantages
• Carbon free when using H_2 and O_2 • Well suited for distributed generation, eliminating distribution losses • Provides base load power (good complement to renewables)	• Safety concerns with hydrogen (though it is less dangerous than gasoline) • Durability, particularly at high temperatures

3.0 DG INTERCONNECTION & PENETRATION LIMIT

3.1 DG PENETRATION

3.1.1 LV Penetration Level : A large penetration of DG will increase current injection to the LV network.

Undesirable overvoltage in the LV networks might occur if the magnitude of DG current injection is greater than the load of the LV networks. Recommendation for DG penetration limits as follows:

a. For residential area with multiple solar PV connection, the maximum allowable solar capacity connected to a single LV feeder is 54 kW. This is to endure that, under worst case scenario without load, the voltage limit of 230 V + 10 % will not be violated.

b. Maximum allowable DG capacity connected to a sub-station at LV side is 90 % of transformer capacity or a maximum of 425 kW, whichever is lower.

c. For DG connection up to 425 kW, connection limit to LV is subject to the finding of CCC. However, in the event that the connection is to MV, then PSS is applicable.

3.1.2 MV Penetration : Total capacity of DG generation connected to a MV distribution system is to be limited to the demand of local distribution system.

Recommended MV penetration limits based on the MV connection points are:

a. Connection at PMU (132/11 kV, 132/33 kV)
   1. Maximum allowable capacity of DG is 85 % of PMU transformer trough load. For solar PV, the maximum allowable capacity is 85 % of PMU transformer trough load during daytime.

b. Connection at PPU (33/11 kV)
   1. For connection at 11 kV, the maximum allowable capacity of DG is 85 % of PPU transformer trough load. For solar PV, the maximum allowable capacity is 85 % of PPU transformer trough load during daytime.

   2. For connection at 33 kV, the maximum allowable capacity of DG is 85 % of PMU transformer trough load. For solar PV, the maximum allowable capacity is 85 % of PMU transformer trough load during daytime.

c. Connection at SSU (33 kV, 11 kV)
   1. Maximum allowable capacity of DG is 50 % of cable capacity from interconnection point to the source.

d. Connection at PE (11 kV)
   1. Maximum allowable capacity of DG is 50 % of cable capacity from interconnection point to the source or 2 MW, whichever is lower.

3.2 CONNECTION SCHEME

3.2.1 Background : The connection scheme clauses take into the following considerations.

a. Safety
b. Connection with least alteration to existing network
c. Cost

3.2.2 Connection types The connections types are as follows

a. LV – single-phase 230 V and three-phase 400 V
b. MV – 11 kV and 33 kV

3.2.3 Feed-In Methods : The feed-in method can be sub categorised as:

a. Direct Feed – Connection point at TNB

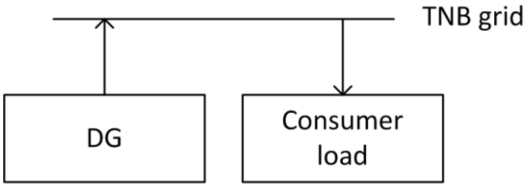


Fig. 3.1 Connection to TNB grid (direct).

b. Indirect Feed – Connection point at consumer load

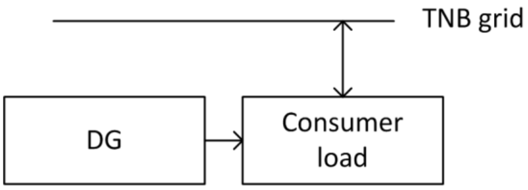


Fig. 3.2 Connection to TNB grid (indirect).

3.2.4 DG Connections Table 3.1 presents various types of DG connection schemes at the LV and MV points.

Table 3.1 DG connection scheme.

DG Source	**Connection Scheme**	**Available Interconnection**		
		LV	**MV**	**MV (Multiple-feed)**

Solar PV	FiT (Direct)	√	√	√
	NEM (Indirect)	√	√	N/A
	LSS (Direct)	N/A	√	√
Biomass/Biogas/ Hydro	FiT (Direct)	√	√	√
Wind Turbine	FiT (Direct)	√	√	√
Energy Storage	Direct (Utility)	√	√	√
	Indirect (Consumer)	√	√	N/A
Co-Generation	Indirect	√	√	N/A

Table 3.2 shows the customer category options for various DG connections. Energy storage also uses the same requirement of a DG.

Table 3.2 Customer categories for various DG connections.

DG Connection	**Customer Category/Available Connection Point**			
	LV Single-Phase	**LV Three-Phase**	**MV 11 kV**	**MV 33 kV**
LV Single-phase	√	√	N/A	N/A
LV Three-Phase	N/A	√	√	N/A
MV 11 kV, PE	N/A	N/A	√	N/A
MV 11 kV, PMU/PPU	N/A	N/A	√	√
MV 33 kV, PMU/PPU	N/A	N/A	N/A	√

Fig. 3.3 shows the planning processes and connection voltage for various proposed DG output power, where PSS is power system studies and CCC is connection confirmation check.

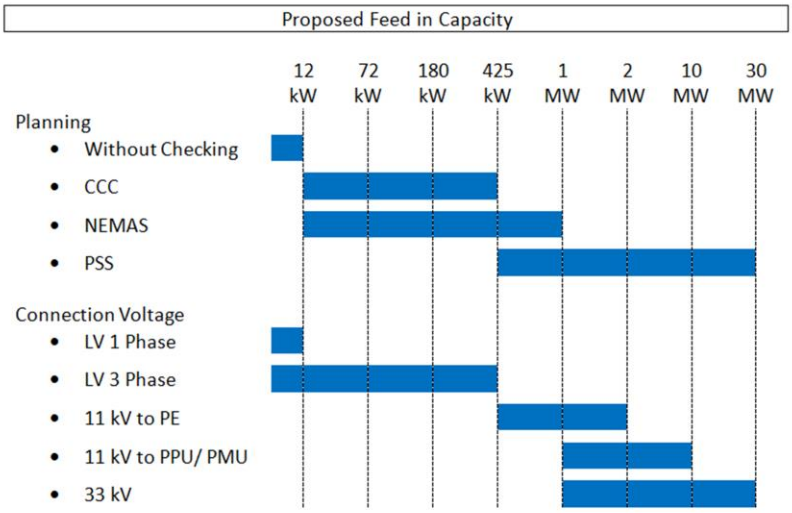


Fig. 3.3 Planning process and point of connection based on proposed DG output.

3.2.5	**LV single-phase 230V and three-phase 400V**	:	The DG's LV output connection can be via direct and indirect connection as shown in Fig. 3.4 and Fig. 3.5, respectively.

a) Direct connection

(i) DG output is connected directly to TNB grid (LVDB/FP).

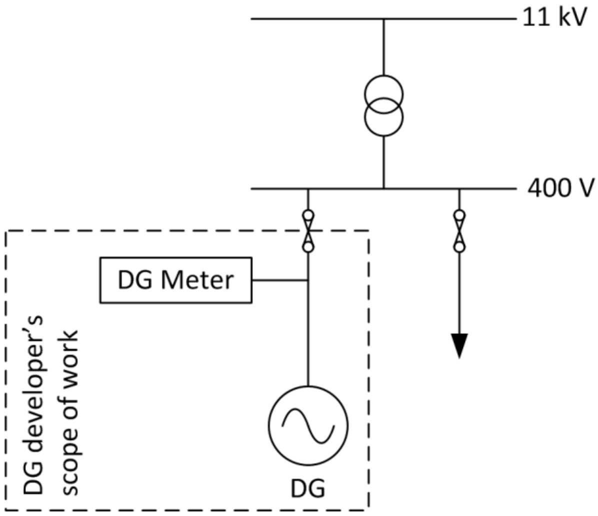


Fig. 3.4(i) DG connections for three-phase LV (direct connection).

(ii) DG output is connected directly to TNB grid (LV grid).

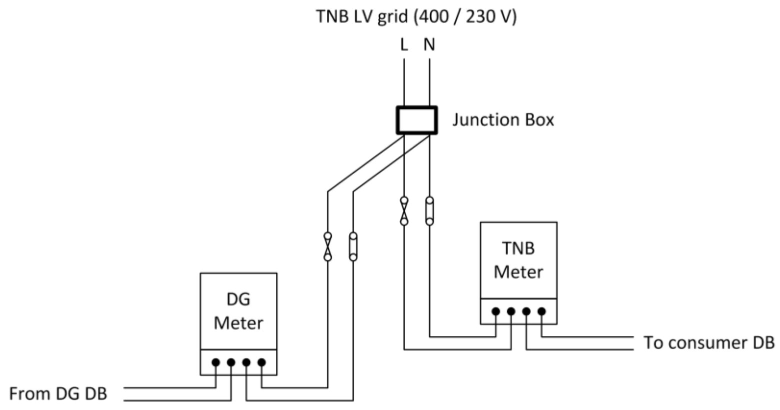


Fig. 3.4(ii) DG connections for single-phase and three-phase LV (direct connection).

b) Indirect connection

Indirect connection is allowed for a special case & requires additional verification & supplementary agreement with TNB.

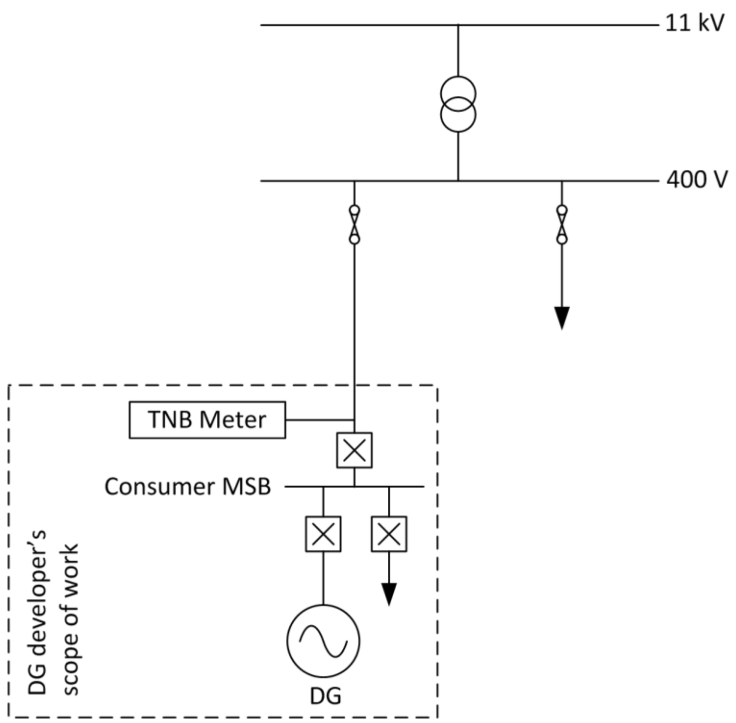
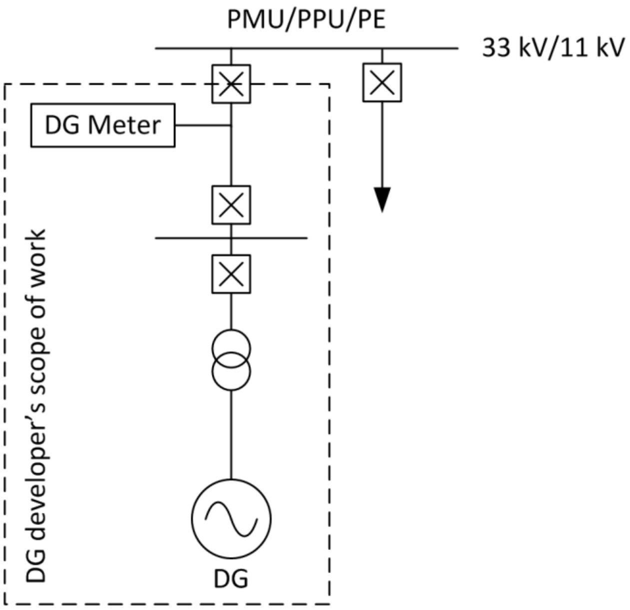
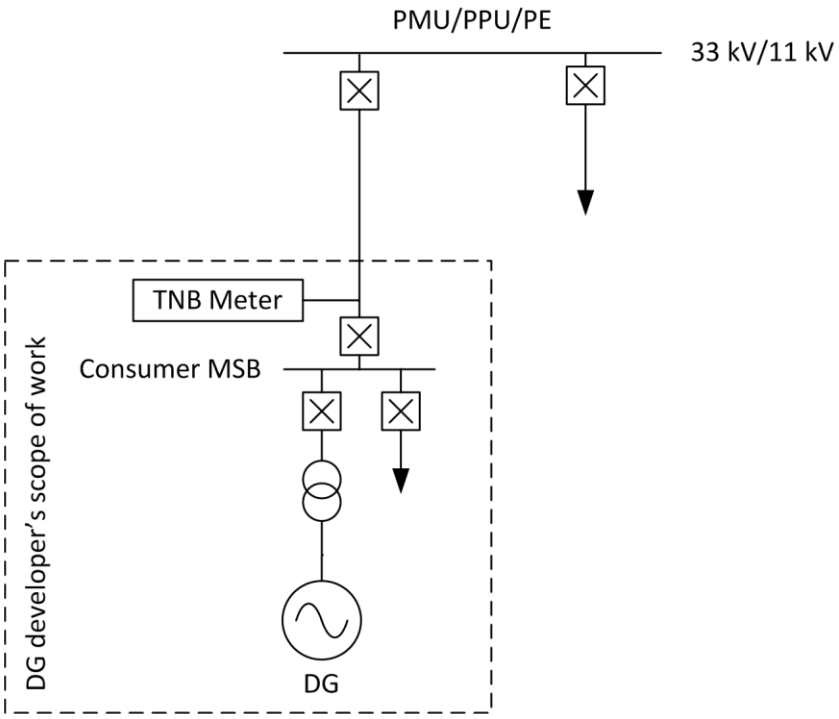


Fig. 3.5 DG connections for single-phase and three-phase LV (indirect connection).

3.2.6	**11 kV and 33 kV, Single and Multiple-Feed Configurations at PMU/PPU/PE (Direct and Indirect Connections)**	Direct and indirect MV connections at the PMU/PPU/PE are shown in Fig. 3.6 and Fig. 3.7, respectively. a. Direct connection  Fig. 3.6 DG connections for MV output at PMU/PPU/PE (direct connection). b. Indirect Connection  Fig. 3.7 DG connections for MV output at PMU/PPU/PE (indirect connection).

In cases where multiple sources of generations are produced and owned within a common site, multiple-feed configuration is allowed to optimise the number of interconnection feeders at PMU/PPU/PE, as shown in Fig. 3.8 and Fig. 3.9.

c. Direct Connection – Multiple Feed

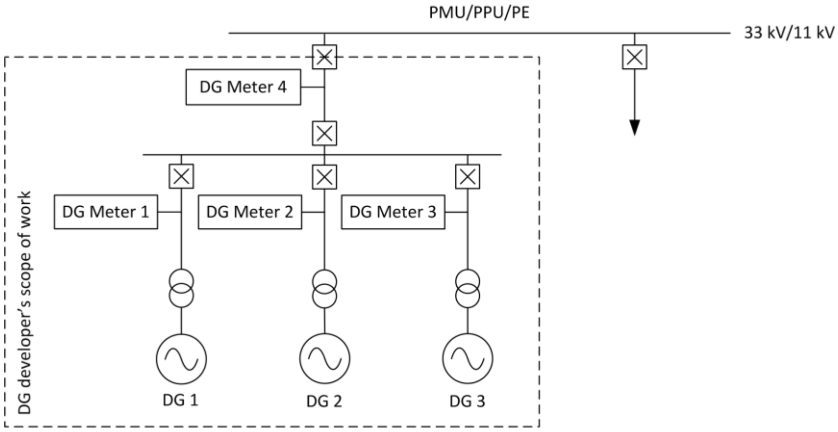


Fig. 3.8 DG connections for MV output at PMU/PPU/PE (direct multiple-feed connection).

3.2.7	**Interconnection Feeder**	:	Interconnection Feeder (IF) is the link between DG developer side and TNB, as shown in Fig. 3.9.

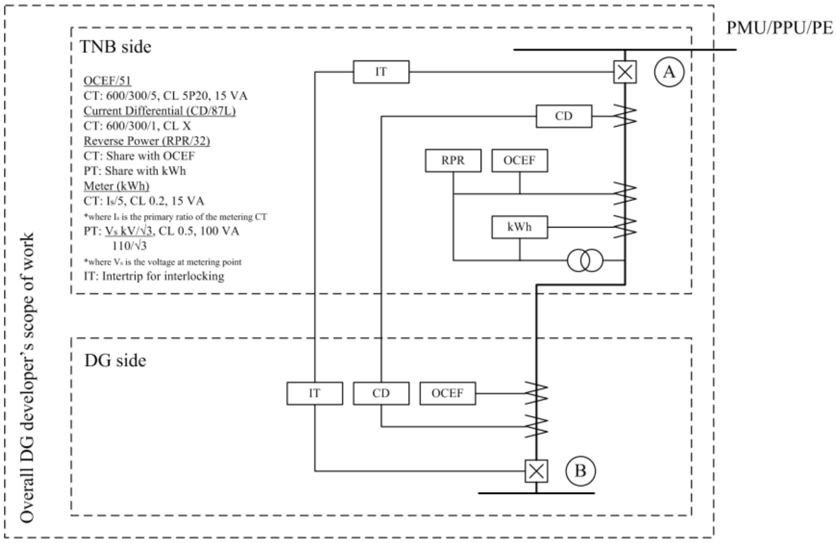


Fig. 3.9 Interconnections diagram between TNB and DG.

3.2.8	**Boundary of Ownership & Operation**	:	The boundary of ownership & operation generally is located at the connection point to the existing network. This is the point which energy is injected into TNB's distribution system. In most cases, it is where the energy meter is located. The interconnection cable belongs to DG developer until the cable termination at the PMU/PPU/PE.

			DG developer is to provide the necessary system expansion required within the scope as stipulated in the T&O Requirements and handover to TNB.
3.2.9	**Equipment Specifications**	:	Equipment that is to be handed over to TNB must comply with the latest TNB technical specifications and approved to be used in the system.
3.2.10	**Approval Process**	:	DG developers are responsible to carry out necessary modification at the connection point to facilitate connection of generated energy. All equipment to be used in TNB's network is subject to approval process by TNB. Approval process include: a. Single line diagram approval. b. "Borang Maklumat Awal" (BMA) for metering. c. Shop drawing approval. d. Factory Acceptance Test. e. Site Acceptance Test. f. Commissioning Test. Prior to commissioning, the DG plant must be tested to ensure that the performance is up to the required standard, installations are according to the approved scheme, settings are done as approved, etc.

4.0 POWER QUALITY

4.1 GENERAL

4.1.1 Regulations : For TNB, the operation of renewable energy interconnection is regulated by the following authorities.

a. Suruhanjaya Tenaga
b. SEDA Malaysia

This document is adapted in compliance to the latest operational conditions and terms as stated in the following document:

a. The Malaysian Distribution Code For Peninsular Malaysia, Sabah & F.T. Labuan (Amendments) 2017
b. Technical Guidebook for the Connection of Generation to the Distribution Network March 2005
c. Guidelines on Large Scale Solar Photovoltaic Plant for Connection to Electricity Networks 2017
d. Guidelines Solar Photovoltaic Installation on Net Energy Metering Scheme 2015
e. TNB Technical Guidebook on Grid-interconnection of Photovoltaic Power Generation System to LV and MV Networks 2013

4.1.2 Scope : DG systems are connected to TNB LV Distribution Network through

1. 230 V – Single phase
2. 400 V – Three phase

DG systems which are connected to TNB MV Distribution System through:

a. 11 kV
b. 33 kV

4.1.3 Connection Requirement : The quality of power provided by the DG system is governed by practices and standards on voltage, flicker, frequency, harmonics and power factor.

Deviation from these standards represents out-of-bounds condition and shall require the DG system to sense the deviation and properly disconnect from utility system.

Power quality parameters (harmonics and voltage) must be measured at the utility interface/point of common coupling (PCC) unless stated otherwise. At PCC, the power quality requirements must comply with the Malaysian Distribution Code and this Technical Guidebook.

a. The measurement before and after energizing the DG must be taken and submitted by the developer to TNB for approval.
b. TNB may request the DG developers to provide power quality measurement at their plants when required.

4.1.4 **System frequency (Distribution Code- 5.4.3.1)** :

During normal steady-state operating condition:-

- Any DG System connected to the Distribution System shall be designed to operate within the normal operating frequency range of 49.5 Hz and 50.5 Hz

During exceptional circumstances :-

- Any DG System connected to the Distribution System shall be designed to withstand short time operation within the range 47 Hz and 52 Hz.

4.1.5 **Steady-state Voltage Limits under Normal Condition (Distribution Code- 5.4.4.1)** :

Under normal conditions, LV DG systems should be capable of operating within the voltage limits as in Table 4.1.

Nominal Voltage (kV)	Steady state voltage limits
11	±5 %
33	±5 %

Table 4.1 Normal operating condition at LV PCC.

Nominal Voltage (V)	Steady state voltage limits
400	+10 % and -6 %
230	+10 % and -6 %

Under normal conditions, MV DG systems should be capable of operating within the voltage limits as in Table 4.2.

Table 4.2 Normal operating condition at MV PCC.

4.1.6 **Voltage unbalance (Distribution Code 5.4.6.6)** :

The maximum negative phase sequence component of the phase voltage on the Distribution System (Voltage Unbalance) shall remain below 1 %, unless abnormal conditions prevail.

Infrequent short duration peaks with a maximum value of 2 % are permitted for Voltage Unbalance.

The unbalance voltage shall not exceed 1 % for 5 occasions within a 30 minute time period at the terminals of a user's installation.

4.1.7 **DC Injection (for DG systems with inverter)** :

The DG system shall not inject DC current greater than 1 % of the rated inverter output current into the utility interface under any operating condition.

4.1.8 **Current Harmonics (Distribution Code- 5.4.6.9)** :

The harmonic of a wave is a component frequency of a wave that is an integer multiple of the fundamental frequency. In the presence of non-linear loads such as computer power supplies and other appliances, alternating current (AC) can be distorted by introduction of various

	(Only for system with inverter)		harmonic frequencies. Harmonics can be measured by percentage of the fundamental frequency or by calculating total harmonic distortion (THD). When present at high levels; these harmonics are detrimental to the electrical system and its loads. The DG system output should have low current-distortion levels to ensure that no adverse effects are caused to other equipment' connected to the utility system. Total harmonic current distortion shall be less than 5 % of the rated inverter output to the PCC. Each individual harmonic shall be limited to the percentages listed in Table 4.3. Even harmonics in these ranges shall be less than 25 % of the lower odd harmonic limits listed.

Table 4.3 Current distortion limits (IEC 61727-2003 Table 1).

Odd harmonics	Distortion limit (%)
3 – 9	< 4.0
11 – 15	< 2.0
17 – 21	< 1.5
23 – 33	< 0.6
Even harmonics	Distortion limit (%)
2 – 8	< 1.0
10 – 32	< 0.5

Note:

- The harmonic current injection should be exclusive of any harmonic currents due to harmonic voltage distortion present in the utility grid without the DG system connected.
- Type tested inverters meeting the above requirements should be deemed to comply without further testing.

4.1.9	**Total Harmonic Distortion Voltage (THD_V) % (Distribution Code : 5.4.6.6)**	:	The maximum total levels of Voltage Harmonic Distortion at any Connection Point on the Distribution System from all sources under both planned outage and unplanned outage conditions, unless abnormal conditions prevail, shall not exceed: a. At 33 kV and 11 kV: a Total Harmonic Distortion of 6.5 %. b. At 400 V and below, a Total Harmonic Distortion of 5 %.
4.1.10	**Power factor**	:	The power factor is defined as the ratio between the applied active (true) power and the apparent power. a. DG systems shall have a power factor ranges from 0.85 lagging to 0.9 leading, above 20 % of the output power level.

4.1.11 Flicker (Distribution Code : 5.4.6.6) : Flicker is due to rapidly changing loads that cause fluctuation in the customer's voltage. Even a small change in voltage can cause noticeable change in brightness of a lighting system that may result in user irritation. The operation of the DG system should not cause voltage flicker in excess of values stated in Table 4.4.

Table 4.4 Maximum allowable flicker severity [11].

Distribution system voltage level which the fluctuating load is connected	Absolute short term flicker severity (Pst)	Absolute long term flicker severity (Plt)
LV Systems	1.0	0.8
11 kV – 33 kV	0.9	0.7
Above 33 kV	0.8	0.6

4.1.12 Short Circuit Levels (Distribution Code : 5.4.6.6)

The Distribution System shall be planned such that the maximum subtransient three phase symmetrical short circuit fault levels are not greater than 90 % of the design short circuit break and make capacity of switchgear connected to the Distribution System and within 90 % of the short time current rating of Equipment connected to the Distribution System.

Table 4.5 Equipment ratings in distribution system.

Nominal Voltage [kV]	Rated Voltage [kV]	Fault Current [kA]
33	36	25
11	12	20
0.4	1.0	31.5

4.1.13 Power Quality Measurement for DG

Pre/Post Initial Operation Date (IOD)

Power quality measurements are to be done at the point of connection to ascertain the existing power quality before commissioning and after the connection of DG plant. The recording period shall be 7 days before commissioning to capture the base voltage regulation profile without DG plant and 7 days after commissioning with the DG plant connected.

Measurement shall capture the following parameters and not limited to:

a) Total harmonic distortion (THD) voltage
b) Unbalanced voltage
c) Flicker voltage
d) Power and energy measurement (kW, kVAr, power factor)

TNB may request power quality measurement at the DG circuit breaker as and when required.

Permanent Power Quality Measurements (Solar LSS only)
Solar LSS developer shall install a permanent power quality recorder at the LSS circuit breaker and to submit the power quality report as and when requested by TNB.

4.2 SPECIFIC CRITERIA FOR SOLAR (MV CONNECTION ONLY) – REQUIREMENTS FOR NETWORK SUPPORT

4.2.1 Low Voltage Ride Through : During disturbance, the distribution system will experience temporary low voltage/sag. The LSS plant is expected to continuously operate during distribution system voltage fluctuation as shown in Fig. 4.1.

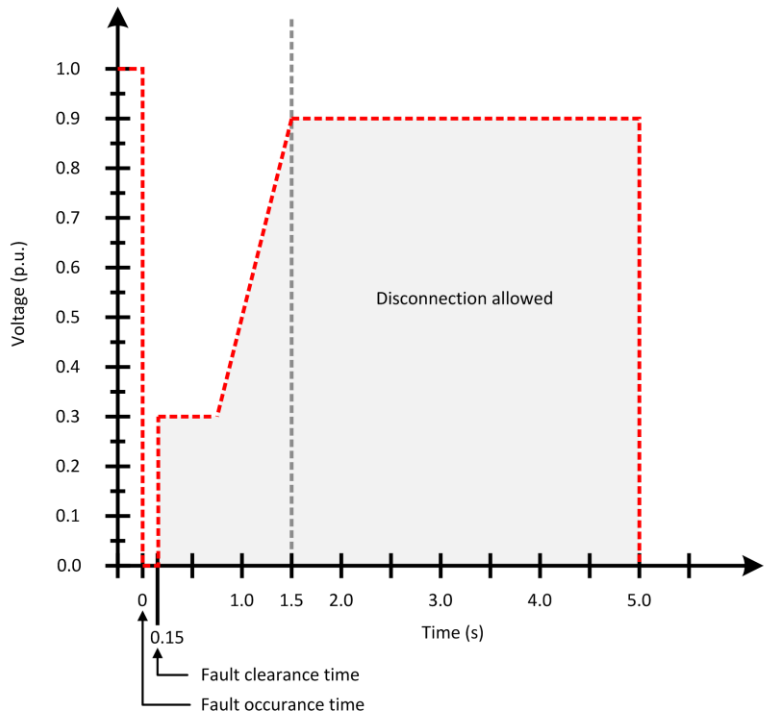


Fig. 4.1 Operation of LSS during system voltage fluctuation.

4.2.2 Voltage Fluctuation : The maximum voltage fluctuation range allowed due to varying solar radiation is 6 %.

4.2.3 Frequency MW Response : The LSS plant is expected to be uninterrupted within the frequency range of 47 Hz to 50.5 Hz.

During frequency disturbance, when the frequency increases more than 50.5 Hz, the LSS plant shall reduce its power output as shown in Fig. 4.2**.**

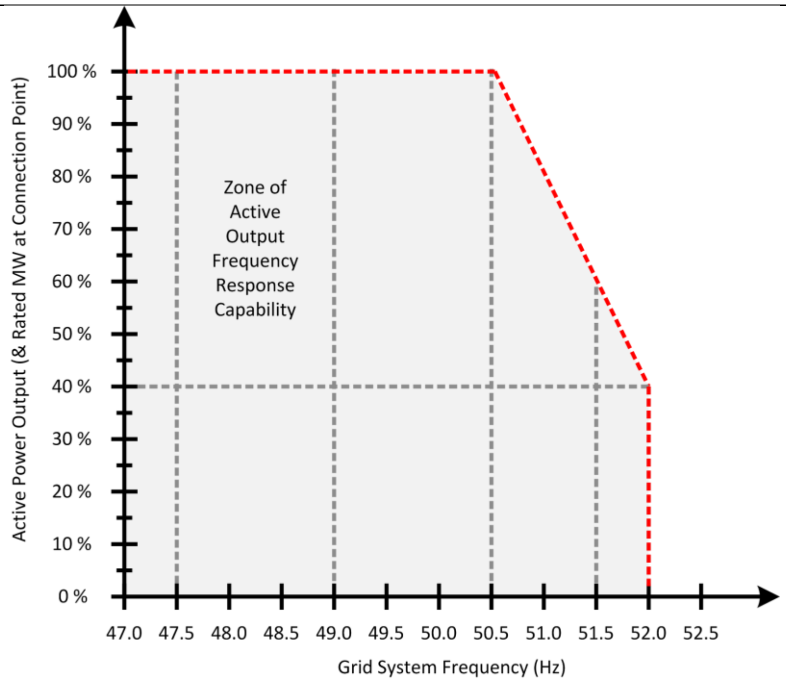


Fig. 4.2 Active power output versus frequency.

4.2.4 **Voltage support (AVQC)** : The LSS plant shall have the capability to manage its power generation as follows:

a) The LSS plant shall be able to reduce power output or disconnect from distribution system during system contingencies.
b) The LSS plant shall reduce its generation output to avoid voltage rise above the limit.
c) The LSS plant shall monitor and ensure that power generation does not exceed the contracted capacity.
d) The inverter shall have the capability to perform active/reactive power control for voltage regulation.

4.2.5 **Droop curve** : The LSS plant shall be fitted with a droop controller or equivalent control device to provide frequency response under normal operational conditions.

4.2.6 **Reactive power** : The LSS plant shall be able to deliver the reactive power requirement at the connection point as shown in Fig. 4.3. Full range of reactive power 0.85 lagging to 0.9 leading shall be achieved at 20 % output.

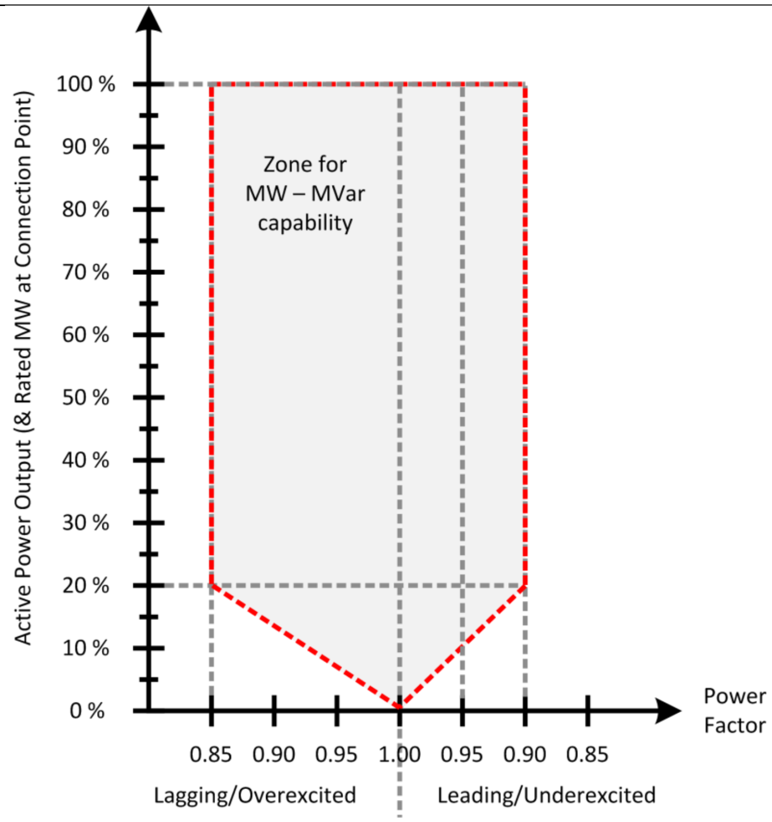


Fig. 4.3 Reactive power requirement at connection point for LSS.

4.3 CRITERIA FOR ENERGY STORAGE

Energy storages to be connected to the Distribution System and at the User interface is required to meet and conform to IEEE 1547 and IEC 62116 technical standards and be compatible with the parameters (voltage, frequency, current rating and short circuit current rating and insulation level) of the Distribution System.

The battery energy storage must be designed to meet the following requirement at PCC [25].

4.3.1	**Voltage**	:	To comply with International Electro technical Commission 61000-3-7, Electromagnetic compatibility (EMC) – Part 3.7: Limits - Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems.
4.3.2	**Harmonics**	:	To comply to IEEE Standard 519, Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems Section 11.
4.3.3	**Voltage Ride Through Capability**	:	The energy storage should comply to the internationally accepted standards on Voltage Ride Through Capability.

4.4 SPECIFIC CRITERIA FOR WIND

All wind turbines connected to the system to adhere to the following guidelines that provide the rules and requirements for the measurement of power quality of Wind Turbine.

IEC 61400-21-CDV: Wind Turbines – Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines [26].

5.0 PROTECTION

5.1 INTRODUCTION : Protection is defined as the provisions for detecting abnormal conditions in a system and initiating fault clearance or actuating signals or indications. Basic protection requirement is that the users arrangements for protection at the connection point, including types of equipment and protection settings, shall be compatible with standard practices on TNB's distribution system.

The protection requirement must be based on the need to detect system faults and malfunctions both within the DG installation and the TNB distribution feeder. On detection of fault or malfunction, the relays must trip appropriate circuit breakers to isolate the faulty section to minimize equipment damage and safety hazards during the faults whilst maintaining power supply continuity on healthy parts of the system.

This protection guideline covers the medium voltage and low voltage levels based on two types of connections:

1. Direct (Eg: FiT, LSS)
2. Indirect (Eg: Net metering and Self-consumption)

5.2 GENERAL GUIDELINES FOR ALL CONNECTIONS

5.2.1 Synchronisation : Synchronisation is an act of matching, within allowable limits, the required DG parameters with the TNB parameters as in Table 5.1.

Table 5.1 Parameters required for synchronisation.

Parameters	**Required range**
Frequency difference	< 0.2 Hz
Voltage magnitude difference	< 10 %
Voltage angle difference	< 10 ^{o}
Interlocking logic are satisfied	-

5.2.2 Shutdown or Tripping : The term shutdown or tripping of the DG refers to an action where the DG stops to energise the utility line. During this period, the following actions should be taken.

For inverter based DG, the inverter :

a) does not completely disconnected from the utility
b) does not completely turn off
c) controls remain active
d) The connection to the utility remains and is maintained for the inverter to continue sensing utility conditions

For non- inverter based DG:

a) completely disconnected from the utility

5.2.3 Failure of DG : DG plant must be disconnected from the distribution system during

Protection or Control Equipment

any of the DG's system failure. For any internal fault, the DG plant shall not cause problems to the utility system and its customers. The failure of the DG plant equipment includes the failures of :

a) Protection equipment
b) Control equipment
c) Interconnection power and fibre optics cables

For any distribution system fault outside the DG plant, the DG plant shall be protected from any damaging effect. During contingency periods when generator sets are used by TNB, DG will not be allowed to be connected to the grid.

5.2.4 Connection Timing : After the DG tripping, no DG reconnection will take place until TNB system is normalized and stabilized based on the minimum connection time shown in Table 5.2.

Table 5.2 Minimum connection time.

Voltage Level	Time
Low Voltage	2 minutes
Medium Voltage	5 minutes

The DG stabilisation period starts once the DG detects the voltage and frequency to be in the normal range. For inverter based DG, the synchronisation is performed at the inverter.

5.2.5 Anti Islanding : DG consumer is to prove the anti-islanding capability of the DG plant during commissioning tests. During islanding, DG plant shall stop energising the grid in case of voltage and frequency violation in the system. Once islanding is detected, the TNB grid network will be disconnected from DG plant through the PCC within 2 seconds of the formation of an island due to:

a) Personnel Safety
b) Power quality

Therefore, the anti-islanding protection will allow to mitigate the abovementioned events.

The DG shall provide the following anti-islanding detection techniques:

a) Under Voltage
b) Over Voltage
c) Under Frequency
d) Over Frequency
e) Additional active/passive anti-islanding technique

			Additionally for Inverter based: A DG system shall sense the TNB utility conditions and stop energising the utility line when the following conditions occur based on the DG type: a) The sensed voltage and frequency lie outside the inverter operating range. b) Excess DC current injection is detected as mentioned in LV and MV guidelines.
5.2.6	**Protection Equipment**	:	The protection relay and PQR equipment to be used is subjected to the approval by TNB.
5.2.7	**Protection Scheme at PCC**	:	DG protection scheme is under DG developer's responsibility and they are to declare the protection scheme and settings to TNB. The protection scheme is based on the connection whether it is direct or indirect. A DG developer shall design, procure and install, and be responsible for the cost, type, design and installation of its own electrical protection scheme in accordance with prudent utility practices. TNB shall ensure that the electrical protection schemes are properly coordinated including power system study for overvoltage protection purpose, for the reliable and safe operation of its electricity distribution system from the main grid until PCC. Upon approval from TNB, the DG developer shall install and test the protection scheme, and witnessed by TNB personnel. The DG developer then shall deliver the electrical protection scheme that contains protection devices which, on the detection of a fault or malfunction, isolate the faulty part of the installation to: a) Minimize equipment damage and safety hazards during such fault or malfunction; and b) Maintain the continuity of power supply to the functioning parts of the installation. The protection at interconnection are as follows: a) Unit Protection (Current Differential) b) OCEF / Non Directional OCEF c) Interlocking scheme Where applicable, the following protection schemes may be required: a) Over-voltage b) Reverse Power Relay c) Arc protection d) Busbar protection e) Automatic transfer scheme
5.2.8	**Protection**	:	The DG developer shall carry out the internal protection coordination

	Co-Ordination Study		to mitigate internal and external fault. The protection coordination study shall cover all protection relays which protect equipment within DG plant. The DG developer shall procure at its own cost a protection co-ordination study to be carried out by a qualified person appointed by him. The DG developer shall submit to the TNB not less than sixty days prior to the initial operation date the following documents: a) The results of the protection co-ordination study; and b) The details of the proposed electrical protection scheme including electrical protection methods, relay types, relay settings and breaker ratings together with the relevant calculations, for the generators, transformers, and interconnecting cables for the purpose of the coordination study. If proposed electrical protection scheme, relay types and relay settings and breaker ratings are not acceptable to TNB: a) The TNB shall specify in writing to DG developer its reason for such non-acceptance; and b) The DG developer shall comply at its own cost with any reasonable request of the TNB to provide an acceptable electrical protection scheme, relay types, relay settings and breaker ratings.
5.2.9	**Inverter as UPS**	:	For any interconnection with TNB, the usage of DG as a UPS to the grid is strictly prohibited.
5.2.10	**Fault Clearance Sequence For Inverter Based Distribution Generation**	:	During abnormal conditions, the inverter shall disconnect either shortly before or after the utility sub-station opens depending on the voltage characteristics sensed; IEC 61727 states that a voltage > 135 % of nominal will be damaging to inverter.
5.2.11	**Inverter Fault Detection**	:	PV system with inverter shall use abnormal voltage or frequency sensing for fault detection.
5.2.12	**Inverter Fault Current Contribution**	:	The fault current contribution by the inverter will be limited usually by inverter control. Based on IEEE 1547, the typical range of short circuit current is between 100 % and 200 % of the rated inverter current. DG developer shall ensure that inverters used comply with the IEEE1547 requirement.
5.2.13	**General guideline Synchronous based**	:	Generator connections and generator protection systems should be designed to a prudent utility practice and conform to current safety and regulatory standards. The following should also be taken into account when designing generator protection systems. a) *Technical specifications for interface equipment* – Protection systems that interface with the network systems, such as any differential protection systems, will need to use approved TNB

specification to ensure compatibility and consistency of performance.

b) *<u>Fault clearance time for generator faults</u>* – There are a number of faults within the generator systems that could affect the stability of distribution system. It may then be necessary for the network operator to define certain protection operation performance. Normally, this is limited to protection operation and fault clearance times.

c) *<u>Unit protection for connection cables</u>* – It has been the practice of the distribution system operator to equip the connection cable with unit protection. This was found to be necessary to protect the network against incorrect co-ordination afforded by slow over-current feeder protection. Where appropriate and economical, the distribution system operator will consider directional current protection.

d) *<u>Example of generator protection system requirements</u>* – Fig. 5.1 include a typical protection system diagram and the minimum requirements for a generator protection system.

e) *<u>Example of connection point requirements</u>* – Fig. 5.1 shows a typical connection minimum requirements including loss-of-mains protection. Specific minimum requirements may include single generator connection and top-up/standby type connections.

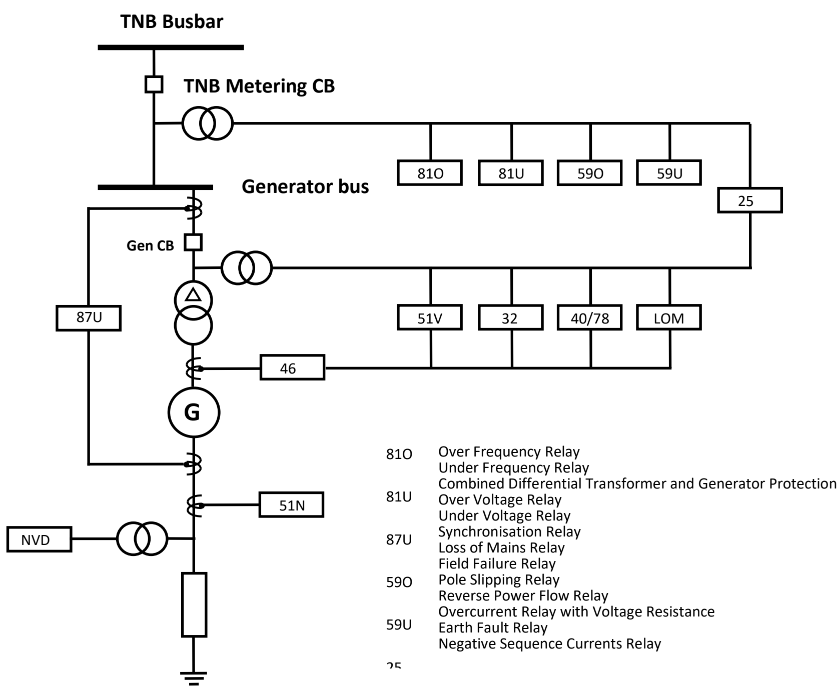


Fig. 5.1 Distributed Generator protection schemes.

f) *<u>Other requirements</u>* - Pole slipping protection could self-protected generators from system instability and may be required as identified by stability studies.

g) *Neutral Voltage Displacement (NVD) protections* – Subject to safety and regulatory considerations, NVD protection could be used on systems where it could be inadvertently un-earthed for a very short time.

h) *Distribution system back-up fault clearance* - Network backup fault clearance can take up to a maximum of 1.2 seconds at the source.

Under voltage (UV) and Under Frequency (UF) relays are designed to trip the generator when the distribution feeder is taken off. When the feeder is supplying load greater than the capacity of the generator, under frequency and under voltage are expected to occur and UV and UF relays will operate to trip the generator. The setting of the under frequency trip (Hz) must be based on the recommendation of the manufacturer.

5.2.14 Earthing Scheme :

- The LSS plant earthing scheme shall not cause mal-operation to TNB protection scheme
- The zero sequence components between TNB network and LSS plant shall be isolated. The LSS plant step up transformer(s) shall have delta (Δ) configuration on TNB side as illustrated in Fig. 5.2 to ensure the plant does not contribute zero sequence current to TNB network during fault.

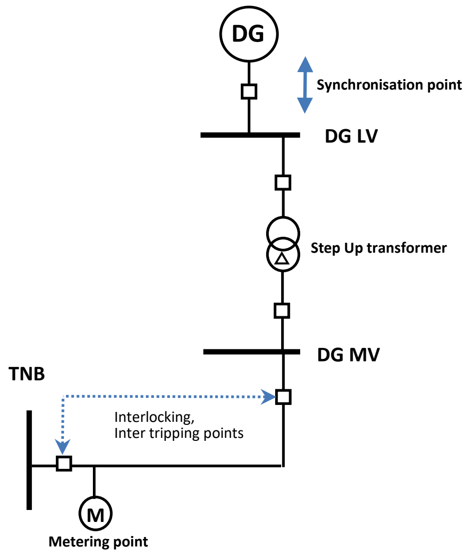


Fig. 5.2 Step up Transformer Earthing Scheme.

5.2.15 Islanded Operation : Islanding within the Distribution system has not been implemented generally. However, there are isolated areas which are supplied by systems which are islanded or capable of being islanded. Generally these would be remote systems where interconnection to the main distribution system is prohibitively expensive. Generator capabilities and its performance within these islanded systems are crucial and need to be controlled. Two main control systems required are voltage and frequency control.

The performance requirements will require sophisticated generator and network control to match generation with demand. Some of the capabilities for generators and the TNB system would include:

a) Isochronous operation
   This type of operation is normally suitable for smaller machines or a single machine supplying a system where the demand is less than the generator output. Isochronous control used in the generator will maintain frequency by increasing or reducing its output. There is a need to maintain a margin between the generator output and the demand. The frequency control can be coarse and may exceed regulatory limits transiently. Load shedding schemes can be used to supplement the frequency control.

b) Governor droop control
   Governor droop control is used for larger systems containing multiple generators. Droop control will allow generators to share their outputs proportionally when maintaining frequency. Some form of fast frequency response systems may be required depending on the nature of the demand are required for fine control. Droop settings will be dependent on the system and its demand.

c) Demand load shedding/frequency tripping systems
   To supplement generator control, demand load shedding can be used for controlling frequency. This system is normally used as an emergency measure. Demand will need to be prioritised for tripping based on acceptable levels of frequency deviation.

d) Seamless Islanding/Black Start
   Seamless Islanding would mean that a customer would not see any supply interruptions. In order to facilitate seamless islanding, all generators that are required to support the island would need to automatically switch to its islanding capabilities described above. These systems may be complex and could be unnecessarily expensive. A manual system could be implemented where generators would need to be equipped with Black Start capabilities. The Islanded Distribution systems are initially allowed to be de-energised and the systems are then re-energized by matching generator output with demand at all stages of restoration. The length of supply interruptions would depend on the speed of restoration of Black Start cells.

   i. Network re-synchronising control and locations
      Restoration of sub-islanded systems to the main networks will require synchronizing points to be identified within the system. Voltage and frequency control between multiple generators would need to be coordinated so that voltage and phase angles could be matched to allow synchronizing.

ii. Loss-of-mains protection
Islanded systems will need to be separated from the main TNB system by loss-of-mains protection. Selection of points of separation is critical to ensure correct islanded operation, for example when matching demand to generation available.

iii. Protection systems
A number of parameters will affect the operation of protection systems when a system is islanded from TNB namely; lower fault levels and different (such as reverse load flows or increased or lowered load flows). Protection systems would need to be capable of switching from a paralleled system to an islanded system.

Islanding system could make a difference in costs of supply failure during forced or planned outages. Where appropriate, case studies should be carried out using real systems to discover benefits, and also costs of realizing the benefits.

5.2.16 Stability : Generators connected to very long lines subject to long protection clearance times could experience transient instability. Multiple generator installations could be particularly prone to instability. Stability studies would be carried out whenever required, to determine the need for additional system and generator protection such as pole slipping protection.

Pole slipping protection system is used to protect the generator from instability and the damage it could cause. However, this is a non-standard protection and will be an additional cost to the DG Developer.

Studies would also need to identify the pole slipping protection settings required. The settings would need to take into account instability within the generator and also within the distribution system caused by other generators in the system.

At the onset of a project, it is unlikely that precise data required for stability studies will be available. It is essential that sensitivity assessments are carried out on estimated generator data in order to identify potential stability problems. Detailed studies may be required once actual data are available, usually when machines are being ordered.

5.3 MEDIUM VOLTAGE CONNECTION DG

5.3.1	**DG Isolation Scheme**	:	The three-phase fault can be developed from a prolonged single-phase fault; it is important for the arching fault to be cleared as quickly as possible. Hence, the arc protection scheme is applied to isolate this type of fault. Each protective relay has its own selective tripping for each feeder compartment. The arc protection will be operated when light exists in the compartment and when the input current from the current transformer exceeds the relay setting. Each compartment has its own light sensor to detect the light input. Fig. 5.3 shows the original arc protection scheme without RE.

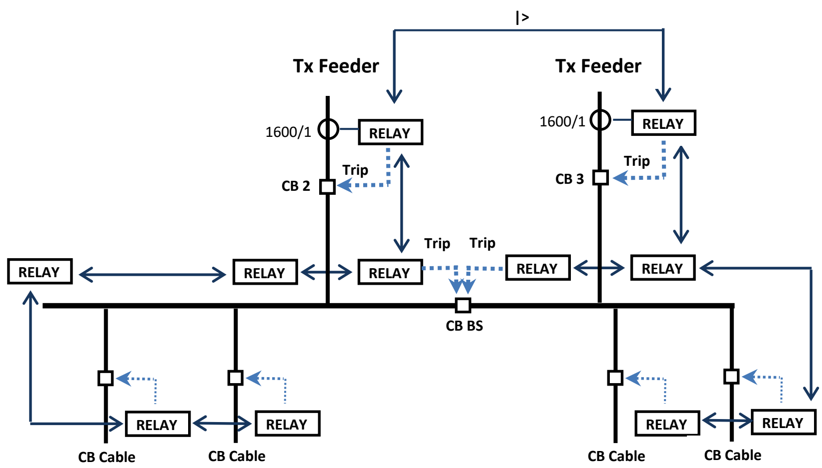


Fig. 5.3 Arc Protection Scheme without RE.

Fig. 5. shows the arc protection scheme with RE. This scheme operates to isolate/trip DG incoming feeder when TNB Incomers are open. The objective of the scheme is to isolate DG feeder upon two transformer feeders in OFF position simultaneously. For the arc protection scheme with DG, tripping the DG incomers is important to avoid sustained flashover from feeding the DG.

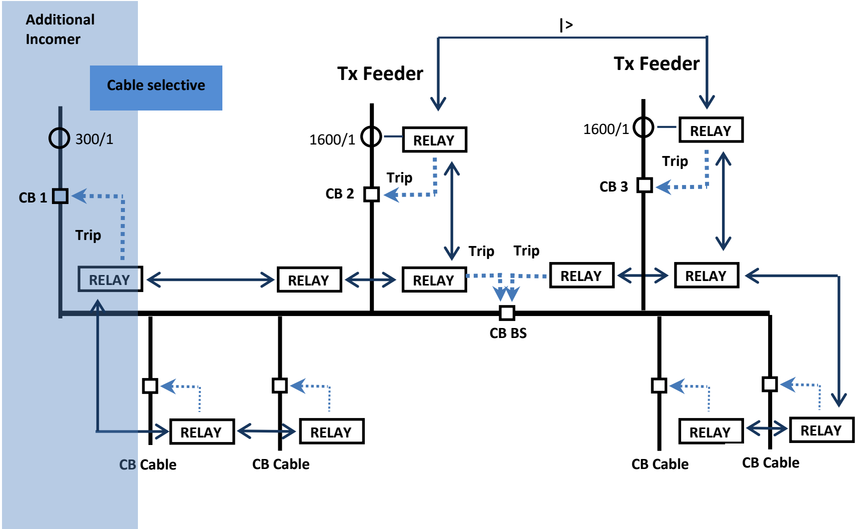


Fig. 5.4 Arc protection with RE.

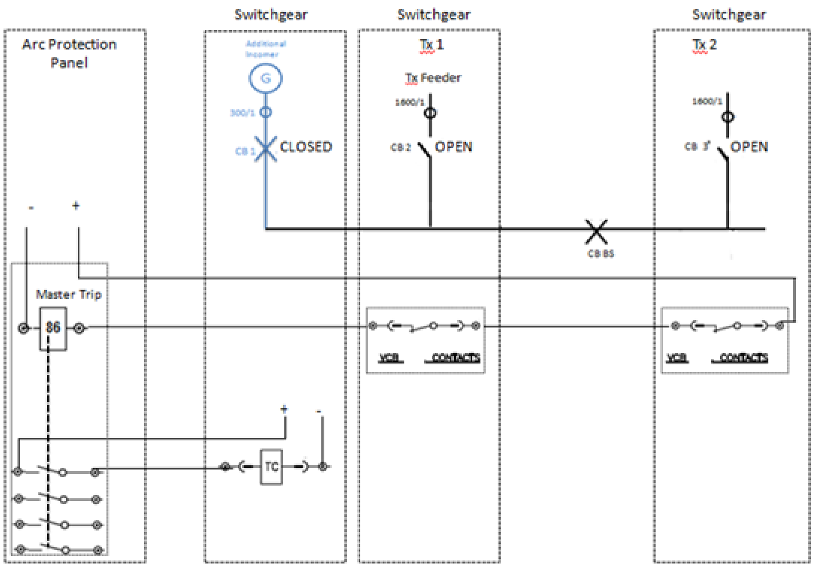


Fig. 5.5 DG isolation scheme for two transformer feeders in OFF status.

Fig 5.5 shows DG isolation scheme while the DG isolation logic circuit is shown in Fig. 5.6. Table 5.3 shows the DG isolation scheme.

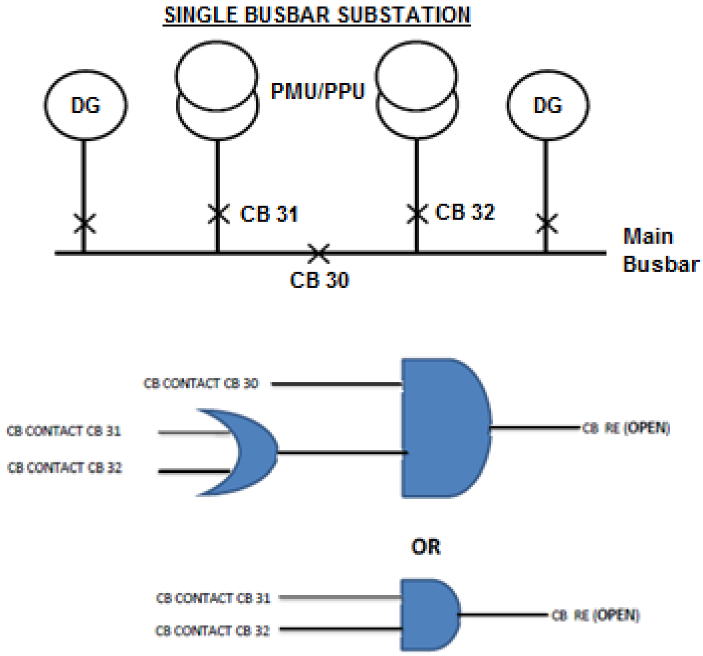


Fig. 5.6 DG Isolation Single Line Diagram and logic.

Table 5.3 DG Isolation Scheme.

Type of Busbar	CB Opening	DG Isolation Scheme
Double Busbar	CB 31 and CB 32	Operate to open DG feeder
Single Busbar	CB 31 and CB 32 **OR**	Operate to open DG feeder
	CB 31 and CB 30 **OR**	Operate to open DG feeder on LHS
	CB 32 and CB 30	Operate to open DG feeder on RHS

5.3.2	**Loss of Mains**	:	Due to network faults, parts of networks containing DG may be inadvertently islanded. Depending on the demand requirements and the generator performance, the DG could remain in operation, thus supporting the island. Protection systems and earthing systems are also not designed for inadvertent generator island systems. For these reasons, it is essential that generator that could potentially support islanded systems is tripped when the condition arise using loss-of-mains protection systems. The use of auto-reclosers also makes it necessary for the loss-of-mains protection to trip the relevant generators before the auto-reclose recloses. The reclosing should be set more than 2 seconds to allow enough time for the generator to be disconnected from the grid. Loss-of-mains protection is usually installed at the DG developer's side. This arrangement would allow a generator to be islanded within its own private network if required. A number of loss-of-mains systems are possible depending on required operation time, network configuration, demand and generator output. 1. ROCOF/Vector Shift The system works on the principle of fast frequency change and waveform shift characterised at the instant when systems are islanded. However, these systems are prone to nuisance tripping because the relay can detect overall grid system disturbance. Generally it will trip more than necessary, depending on the settings. A number of issues have historically been identified with these systems namely: a) <u>Settings</u> - finding suitable settings may be difficult. It may be necessary to estimate initial settings and monitor its behaviour. Simulating credible system disturbances can assist be used to estimate settings. b) <u>Demand to Generation balance</u> – There may be cases where demand almost equals generation output and the rate of change of frequency or vector shift is not sufficient to cause operation. c) <u>Testing</u> - On site operational testing will be a problem. System monitoring is an option. 2. Generator overload in combination with Over/Under Voltage and Over/Under Frequency If the potential islanding configuration has demand greater than the generator overload setting, an over-current protection relay could be an effective loss-of-mains protection. However, in the assessment, consideration must be taken during light load conditions where the condition may not be true and other loss-of-mains of protection as described above needs to be installed. 3. Over/Under Voltage and Over/Under frequency Over/Under Voltage and Over and Under Frequency protection systems are the minimum requirement at the connection point. These protection relays normally take longer to operate than those

			described above and thus may not be suitable for use with auto-reclosers.
5.3.3	**Auto-Reclosing**	:	The auto reclosing system is used to reclose lines that are tripped by self-clearing faults. Auto reclosing lines that have generators connected within the system could result in out of phase closing. The impact of connecting out-of-phase systems could be destructive and could lead to: a) Extensive Generator Damage; b) Network Circuit Breaker Damage; and c) Network Voltage Sag due to the high currents caused when connecting out-of-phase systems. Reliable and fast loss-of-mains tripping will be required where reclosers are used in systems that can be potentially islanded for a short period. Normally, the use of intertripping for loss-of-mains would provide the reliability and speed of operation. The use of over-current relays for loss-of-mains may also be suitable, provided the speed of over-current operation is faster than the auto-reclosing time.
5.3.4	**Interlocking**	:	DG unit control system must include synchronization facilities to enable the generator to be connected to the distribution system, Control facilities and methods to be employed for synchronization will need to be approved by TNB. An automatic synchronizing panel from a recognized manufacturer, designed for the type of machine proposed, will normally be acceptable. Synchronisation point is usually a breaker under the operational responsibility of the DG developer. This synchronization point and the breaker must be adjacent to the breaker under the operational responsibility of TNB. Locations of synchronizing facilities for various connection configurations are illustrated in Fig. 5.7 and Fig. 5.8.

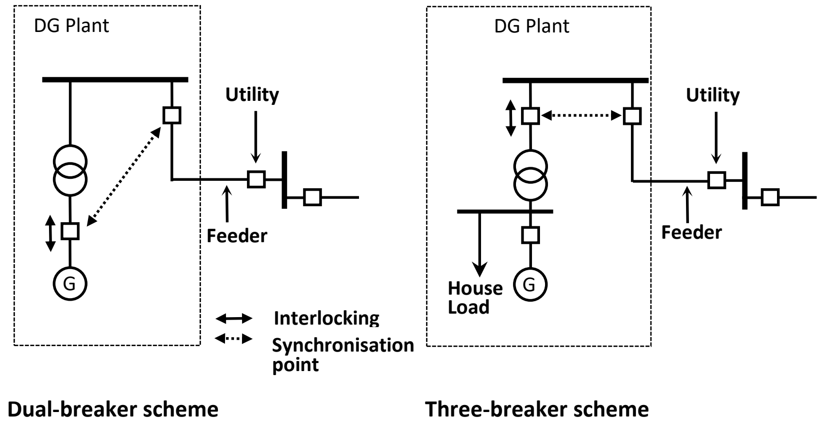


Fig. 5.7 Synchronisation points and interlocks (1).

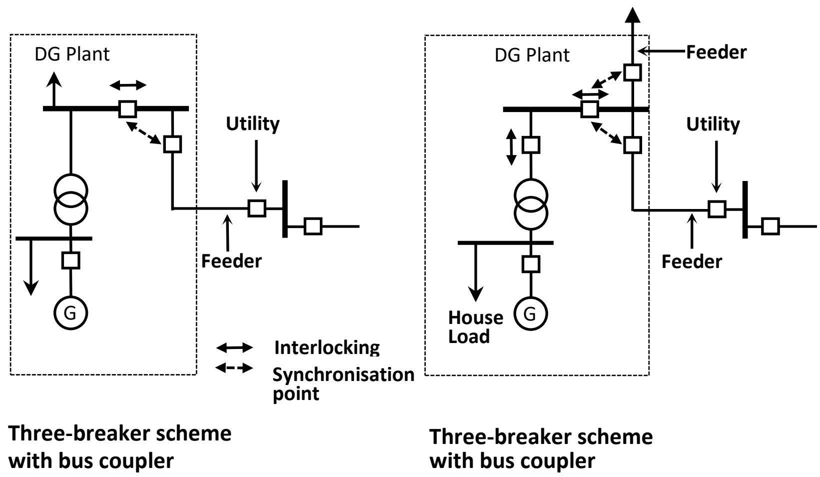


Fig. 5.8 Synchronisation points and interlocks (2).

5.3.5	**Contingency**	:	Under contingency condition, when one or more circuit elements are on outage – scheduled or non-scheduled.
5.3.6	**Interlocking Of The Interconnection Feeder**	:	The interlocking facilities shall operate in the following manner, referring to Fig. 5.9. • A open – B to open • B close position – A cannot close • A open position – B cannot close • Earth Switch (ES) B ON – A cannot close

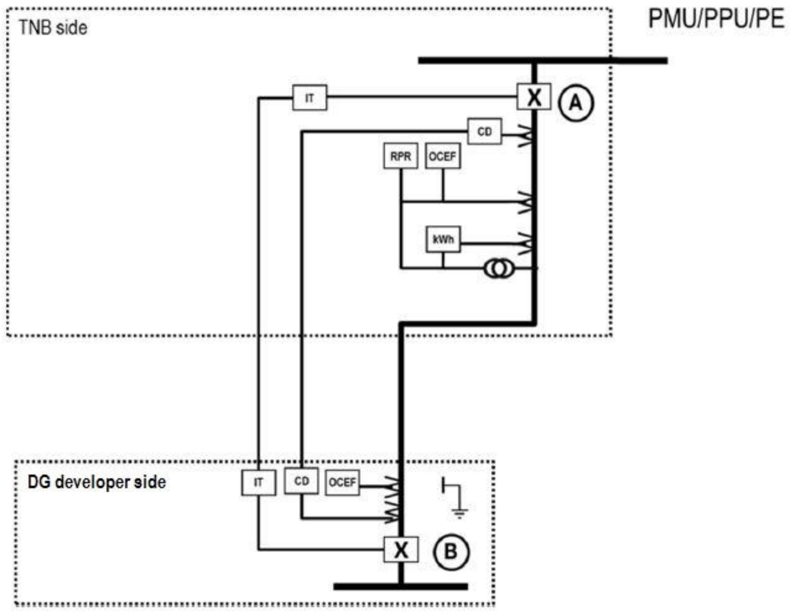


Fig. 5.9 Interlocking of the interconnection feeder with TNB.

5.4 LOW VOLTAGE CONNECTION DG

5.4.1 LV Connection : For LV connection, the DG is connected to a substation feeder pillar through a link and shall be protected by fuses as shown in Fig 5.10. The number of connections cable is based on the DG capacity.

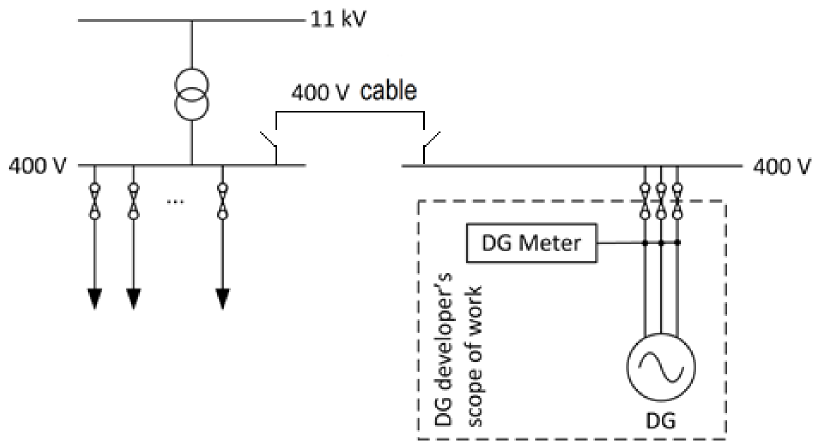


Fig 5.10 LV Connection DG.

5.5 ENERGY STORAGE

5.5.1 Introduction : Energy storage is still new and developing in Malaysian system.

Therefore, this section serves as a preliminary reference which is subjected to change and further review.

5.5.2 Governor System Requirements : A battery energy storage facility must have a continuously acting governor system, which must be designed:

(a) to be continuously in service, free to respond to frequency changes and controlling the response to frequency changes while the battery energy storage facility is connected to the transmission system;
(b) with a droop setting equal to or greater than 3 % but less than or equal to 5 %, which droop-setting must be based on the difference between the maximum authorized charging power and maximum authorized discharging power;
(c) with a deadband, intentional plus unintentional, not exceeding plus or minus 0.036 Hz;
(d) with the capability of manual setpoint adjustments within a range of 49.5 Hz and 50.5 Hz; and
(e) at a rate of 5.0 % of the difference between the maximum authorized charging power and the maximum authorized discharging power per second.

A battery energy storage facility must be designed not to trip for under-frequency and over-frequency deviations for the minimum time frames shown in Table 5.4 and Fig 5.11.

Table 5.4 Frequency Ranges.

Frequency Ranges High Frequency Duration		**Low Frequency Duration**	
Frequency (Hz)	**Time (seconds)**	**Frequency (Hz)**	**Time (seconds)**
≥ 61.7	Instantaneous trip	≤ 57.0	Instantaneous trip
≥ 61.6	30	≤ 57.3	0.75
≥ 60.6	180	≤ 57.8	7.5
< 60.6	Continuous operation	≤ 58.4	30
≤ 59.4		180	
> 59.4		Continuous operation	

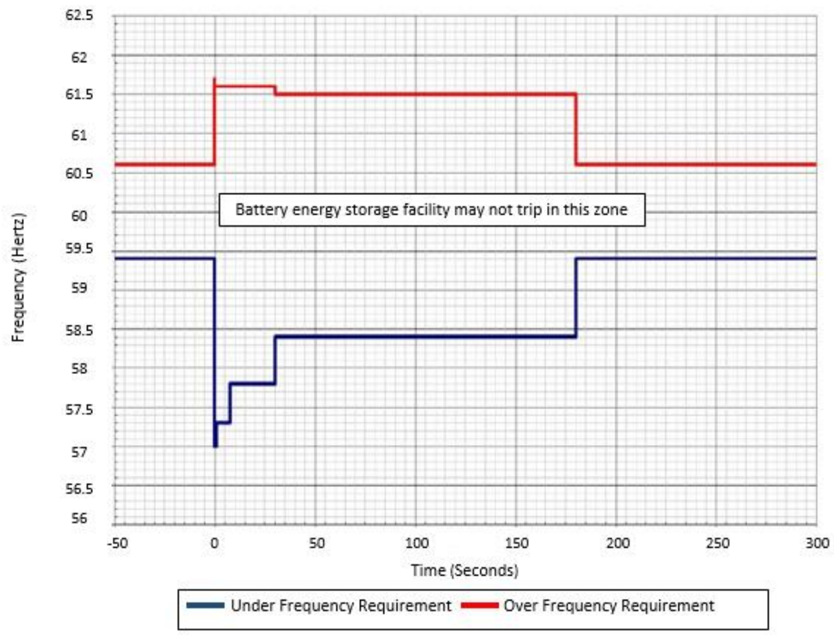


Fig. 5.11 Frequency Ranges.

5.5.3 Ramp Rate Limitations :

A battery energy storage facility must be equipped with ramp rate limiting controls that are capable of limiting the ramp up or down of the real power of the battery energy storage facility for the purpose of responding to dispatches or directives.

A battery energy storage facility must be designed such that the default settings for the ramp rate limiting are set at 10 % of the difference between the maximum authorized charging power and maximum authorized discharging power.

A battery energy storage facility may participate in an ancillary service at the ramp rate defined by the technical requirements for that ancillary service.

5.5.4 Power System Stabilizer :

The legal owner of a battery energy storage facility to use a power system stabilizer for the battery energy storage facility that is specified by WECC.

5.5.5 Transmission System Step-Up Transformer :

The legal owner of a battery energy storage facility must ensure that the capability of the transmission system step-up transformer for the battery energy storage facility is such that the real power and reactive power requirements specified in this rule are fully available throughout the continuous operating voltage range for the battery energy storage facility.

The legal owner of a battery energy storage facility must, in determining the capability of the transmission system step-up transformer, consider the following:

(a) The thermal capability of:
   i. bushings;
   ii. windings; and
   iii. the tap changer;
(b) The voltage ratio;
(c) The tap changer type;
(d) The tap changer range; and

			(e) Any other components that may limit the thermal capability of the transmission system step-up transformer. The legal owner of a battery energy storage facility may subtract the amount of auxiliary load in apparent power from the apparent power capability of the battery energy storage facility at the greater of the maximum authorized charging power or the maximum authorized discharging power, but only if any of that auxiliary system load is connected between the battery energy storage facility converter and the low side of the transmission system step-up transformer. The legal owner of a battery energy storage facility must ensure that the transmission system step-up transformer winding connections for the battery energy storage facility provide for: (a) A favourable circuit to block the transmission of harmonic currents; (b) Isolation of transmission system and low voltage side ground fault current contributions; (c) An effectively grounded wye connection on the high voltage side of the transformer; (d) On-load or off-load tap changers with a minimum capability of plus or minus 5 % voltage range in 2.5 % increments.
5.5.6	**Auxiliary Systems**	:	When multiple battery energy storage facilities are at a common location, the auxiliary systems of each battery energy storage facility must be designed such that: (a) The failure of a single component will not result in the simultaneous tripping or shutdown of two (2) or more battery energy storage facilities; and (b) Staggered shutdowns of each battery energy storage facility must be separated in time by more than ten (10) minutes. The auxiliary systems of each battery energy storage facility must be designed to take into account the voltage ride-through requirements.
5.5.7	**Battery Energy Storage Facility Disconnection And Interrupting Devices**	:	The legal owner of a battery energy storage facility and the legal owner of the transmission facility to which the battery energy storage facility is connected must ensure that there are circuit breakers and controls that will electrically disconnect the battery energy storage facility from the transmission system at the point of connection. The legal owner of a battery energy storage facility and the legal owner of the transmission facility to which the battery energy storage facility is connected must ensure that the battery energy storage facility provides the functionality and remote control capabilities to enable the operator of the transmission facility to which the battery energy storage facility is connected to open or trip any connecting breaker. The legal owner of a battery energy storage facility and the legal

			owner of the transmission facility to which the battery energy storage facility is connected must not use fuses at 60 kV or higher.
5.5.8	**Isolation Devices**	:	The legal owner of a battery energy storage facility and the legal owner of the transmission facility to which the battery energy storage facility is connected must ensure that: (a) the battery energy storage facility has a minimum of one (1) isolation device with manual operating capability at a point of isolation; and (b) The isolation device(s) must: i. ermit visual verification of electrical isolation and must be capable of being locked open with two (2) or more locks; ii. be under the control of a single control authority as confirmed by a joint operating agreement between the legal owner of the battery energy storage facility and the legal owner of the transmission facility; and iii. permit the installation of temporary safety earthing so that either side of the isolation device can be safely maintained when the other side is energized.
5.5.9	**Earthing**	:	A battery energy storage facility must be designed to operate within a transmission system that operates as an effectively earthing system.
5.5.10	**Lightning And Other Surge Protection**	:	The lightning surge protection for the sub-station equipment within a battery energy storage facility must be designed to take into account the average lightning ground-flash density level for the site location of the battery energy storage facility and to be compatible with the connecting transmission facility to ensure coordination of insulation levels.
5.5.11	**Synchro phasor Measurement System**	:	A battery energy storage facility must be equipped with a synchro phasor measurement system. The synchro phasor measurement system must be designed to record at the following locations: (a) at the low side of the transmission system step-up transformer of the battery energy storage facility for all three (3) phase-to-ground voltages and currents; and (b) at the high side of the transmission system step-up transformer of the battery energy storage facility for all three (3) phase-to-ground voltages and currents. Where a battery energy storage facility has a common point of connection with a generating asset, the synchro phasor measurement system: (a) must have dedicated voltage and current channels for the feeder to the battery energy storage facility at the low side of the transmission system step-up transformer; and (b) may have common voltage and current channels at the high side of the transmission system step-up transformer. The legal owner of a battery energy storage facility must design a synchro phasor measurement system that is capable of downloading and retaining the recordings for a period of not less than one (1)

			calendar year from the date of the initial recording, unless the ISO indicates otherwise in the functional specification for the battery energy storage facility.
5.5.12	**Internal Sequence Of Event Monitoring**	:	A battery energy storage facility must have an internal sequence of event monitoring system that initiates an event record for every event that results in a trip of the battery energy storage facility. The legal owner of the battery energy storage facility must design a sequence of event monitoring system that is capable of downloading and retaining the recordings for a period of not less than one (1) calendar year from the date of the initial recording. The sequence of event monitoring system must be synchronized to within one (1) millisecond of the Coordinated Universal Time scale.

6.0 SCADA		
6.1 SCADA AND AUTOMATION **(Adopted From TNB DG Guidebook)**	:	For DG interconnection with total capacity of 1 MW and above (AC at the interconnection point), the DG interface/connection point must be equipped with Remote Terminal Units (RTU) c/w Marshalling cubicle and communication system from DG plant to TNB control centre. The RTU shall have capabilities to monitor the following, subject to TNB's discretion: a. Frequency (Hz) b. Voltage (V) c. Current (A) d. Real Power Energy flow (kW or MW) e. Reactive power energy flow (kVAR or MVAR) f. Energy meters g. Breaker status h. Switch status i. Relay indication, where appropriate j. Earth Fault Indicator, where appropriate Where appropriate, derived values, for example the real power from voltage and current phasors would be acceptable. a. If remote control of switches that are in the jurisdiction/area of responsibility of TNB are required to be installed at TNB's control centre, this shall be able to be executed via RTUs. RTU must be able to be communicate with TNB Master system using IEC 60870-5-101 TNB matrix or protocol determined by TNB. b. The facility to control the circuit breaker through Local/Remote/Supervisory must be included in the interfacing sub-station. c. All RTU must be listed in TNB's approved list.

7.0 METERING

7.1 INTRODUCTION :

All energy meters used for measuring the import and export of electricity by developer shall comply with TNB's specifications. The meters shall be procured from TNB. The developer shall bear all costs of meter installation, meter replacement, supply upgrading, and system connection/modification (if applicable).

TNB shall determine the point at which every supply line shall terminate in any premise in view of ease of accessibility to TNB's personnel. At any point in the premises at which supply line or lines terminate, the developer shall provide the meter board, meter panel or meter cubicle according to TNB's specifications for the installation of meter and their accessories. TNB may change any meter and its accessories or their positions in any premise as deemed necessary at any time for purposes of maintenance and meter reading.

The developer shall ensure that the General Packet Radio Service (GPRS) signal strength or any other mode of communication approved by TNB in the metering room is adequate or sufficient for effective GPRS communication of Remote Meter Reading (RMR). The developer shall obtain advice from TNB on the minimum signal strength to be used for RMR. Signal strength shall be -77dBm and above.

7.2 ENERGY METER FOR DIRECT CONNECTED DGs :

The contents in Section 7.2 are applicable to all direct connected DGs, excluding energy storage.

Low Voltage:

For LV connection requiring CT metering, the meters shall be procured from TNB. The developer shall bear all costs of meter installation, meter replacement, supply upgrading, and system connection/modification (if applicable). The LVCT shall be of the single ratio and single purpose type based on specifications that have been approved by TNB. The details of the LVCT are shown in Table 7.1.

Table 7.1 LVCT metering.

Category	**Specification**	
	150/5 A – 400/5 A	**500/5 A and above**
Class	0.5	0.2
Accuracy	± 0.5 %	± 0.2 %
Burden	7.5 VA	7.5 VA

For LV supply without CT metering, the metering scheme is divided into two (2) categories:

a. Single Phase Whole Current Supply:

This metering scheme applies to individual domestic and non-domestic developers.

b. Three Phase Whole Current Supply:

This metering scheme applies to individual domestic and non-domestic developers.

Medium Voltage:

For MV connection, the developer shall provide the CT and VT metering according to TNB's specifications. TNB will confirm the size of CTs for any interconnection after receiving Borang Maklumat Awal (BMA). The Electrical Consultant/Registered Electrical Contractor shall ensure clear understanding of TNB metering requirements. For details on the metering requirement, developers shall refer to the latest Electricity Supply Application Handbook. The details of the MVCT and MVVT are shown in Table 7.2 and Table 7.3, respectively.

Table 7.2 MVCT metering.

Category	**Specification**	
	For connection of 11 kV and 33 kV (indoor breaker)	**For connection of 33 kV (outdoor breaker)**
Ratio	$\frac{I_s}{5A}$ * where I_s is the primary ratio of the metering CT	$\frac{I_s}{1A}$ * where I_s is the primary ratio of the metering CT
Class	0.2	0.2
Accuracy	± 0.2 %	± 0.2 %
Burden	15 VA	30 VA
Unit	3 nos. for each feeder	3 nos. for each feeder
Standards	IEC 61869-2	IEC 61869-2

Table 7.3 MVVT metering.

Category	Specification
	For connection of 11 kV and 33 kV
Ratio	$\frac{V_s / \sqrt{3}V}{110 / \sqrt{3}V}$ * where V_s is the voltage at metering point
Class	0.5
Accuracy	± 0.5 %
Burden	50 VA minimum. *Sharing can be allowed if separate fusing is provided and the burden of the shared load shall not exceed 10 VA. If the burden of the shared load is more than 10 VA, then 100 VA VT shall be used.
Voltage factor	1.9 for 8 hours
Unit	3 nos. for each feeder
Standards	IEC 61869-3

7.3 ENERGY METER FOR INDIRECT CONNECTED DGs	:	The contents in Section 7.3 are applicable to all indirect connected DGs, including energy storage and co-generation. Existing single phase and three phase whole current meter needs to be replaced to a bi-directional meter. The existing meter board and its wiring (if required) shall be re-located or replaced by the registered wireman appointed by the developer. The location of the meter shall be accessible to TNB personnel, facing the main entrance and comply with the latest Electricity Supply Application Handbook. The developer shall bear all costs associated with the connection of indirect DG generation, energy storage and co-generation systems including costs of meter replacement, supply upgrading, and system connection/modification (if applicable). Energy meters as depicted in Fig. 7.1 are required to measure the monthly TNB-developer import and export (M_1) for the purpose of net energy meter reading.

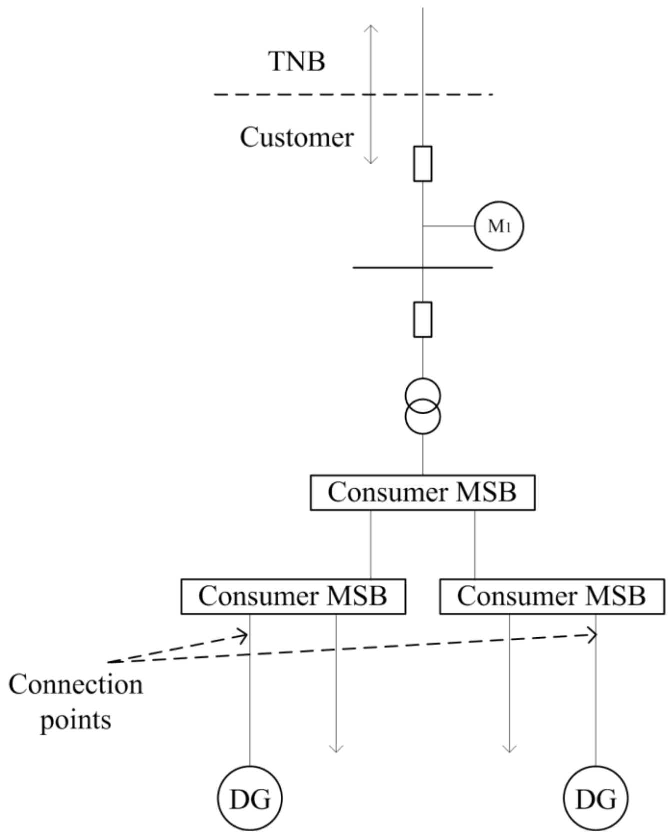


Fig 7.1. Location of energy meters.

7.4 METERING BOARD/ PANEL/ CUBICLE	:	The meter board, meter panel or meter cubicle shall be designed according to TNB's specifications. The developer shall prepare the cabling for the meter which shall be exposed. The developer shall conduct the relevant test as per the TNB requirements and ensure the metering system is in good condition.

		Appendix A, Appendix B and Appendix C present the layout of three phase whole current LV metering panel, layout of LVCT metering panel and a typical MV metering kiosk, respectively.
7.5 METER APPLICATION AND APPROVAL	:	The developer shall liaise with Sustainable Energy Development Section, TNB on the requirements for meter application and approval. Test certificate and wiring diagram of the MVCT and MVVT shall be supplied by developer. The MVCT and MVVT shall have a valid test certificate from an accredited laboratory. The developer shall send the MVCT to TNB for calibration and all costs shall be borne by the developer.
7.6 METER READING	:	Meter reading is remotely taken from TNB office. The developer can obtain the meter reading through: a. The installation of the CT, VT (if applicable) and the meter at the developer's DG side (at the same voltage level as TNB meter) for estimated meter reading and comparison purposes. b. Software to read TNB meter remotely. This software together with the associated services can be obtained from TNB meter provider or related third-party companies. c. Related third-party companies who provide internet-based meter data reading services based on connection and output pulse of TNB meter. The developer may at any time submit a written request to TNB to inspect or test the energy meters. If the meters are found to be defective or inaccurate, both TNB and the developer shall recalculate and agree on the amount payable during the period of inaccuracy. However, if the meter is accurate, the cost for energy meter testing shall be borne by developer.

8.0 SAFETY

8.1 INTRODUCTION

The connections of the distributed generation (DG) systems to the network shall comply with public safety standards as required by Electricity Supply Act 1990 [27] and Electricity Regulation 1994 [28] and other relevant standards and guidelines [29-33]. The operation of the distributed generator systems shall not present a significant risk of serious harm to workers, member of the public and significant damage to property [29]. To ensure compliance, generators are requested to carry out their own safety checks regularly using the appropriate assessment methods [29, 30].

8.2 KEY ASPECTS FOR ADDRESSING DISTRIBUTED GENERATION SAFETY [29-33]

a. Safety of any new technology can be broadly viewed as having three intimately linked aspects as follows:
   1) The system must be engineered and validated to the highest level of safety,
   2) Techniques and processes must be developed to respond to incidents when they occur,
   3) Best practices and system requirements must be reflected in safety codes, standards and regulations (CSR) so that there is uniform, consistent, understandable and enforceable criteria that must be satisfied when designing, building, testing, and deploying the system.

b. As the materials, technologies, and deployment applications for distributed generation are created, new techniques and protocols must be developed to validate their safety and ensure the risk of failure and loss is minimized.

c. These new techniques and protocols will allow manufacturers to design the systems to be as safe as possible, especially for the first and second emergency responders.

d. These techniques will additionally be used to educate first emergency responders on the associated risk of responding to an incident involving the new technologies.

e. Codes, standards, and regulations shall be developed to efficiently memorialize the design rules, response procedures and safety performance metrics to all stakeholders.

8.3 SAFETY DOCUMENTATION [29-33]

a. Safety-related criteria in the form of codes, standards and regulations that apply to system components and deployments need to be updated to reflect the growing verity of distributed generation technologies.

b. This document additionally highlights four key elements:
   1) Distributed Generation Systems safety technology
   2) Risk assessment and management (training,

	communication, method statement) 3) Incident preparedness 4) Codes, standards and regulations
8.4 INCIDENT PREPAREDNESS [29-33] :	a. Emergency preparedness manual shall be developed to respond to any incident should it occur to protect the lives of anyone involved and minimize the damage. b. The Emergency Preparedness Manual shall include the following information, but is not limited to: 1. Map of site 2. Emergency Contact Information 3. General Emergency Procedures 4. Evacuation Procedures 5. Fire Safety Procedures 6. Power Outage Procedures 7. Earthquake Procedures 8. Public safety 9. Critical Incident Reporting Procedures 10. Participant Profiles 11. Emergency Supplies Lists c. There must be a deliberate and concerted effort to engage the first responder community early in the design and siting of distributed generation systems so that proper mitigation techniques can be developed and systems designed to improve the overall safety and ability to quickly and safety resolve the incident.

9.0 APPLICATION PROCESS

9.1 INTRODUCTION : All DG systems to be connected to the grid shall perform technical assessment with Distribution Licensee prior to application to the Implementing Agency.

The purposes of the technical assessment are for the following benefits:

a. determine technical requirements needed for interconnection;
b. ensure the safe penetration of the DG system; and
c. assist applicant to decide on the feasibility of the project in terms of cost.

9.2 APPLICATION PROCESS : The application processes differ for direct and indirect connections to the TNB. DG systems that export to TNB are categorized as direct connections and shall follow the process flow shown in Fig. 9.1.

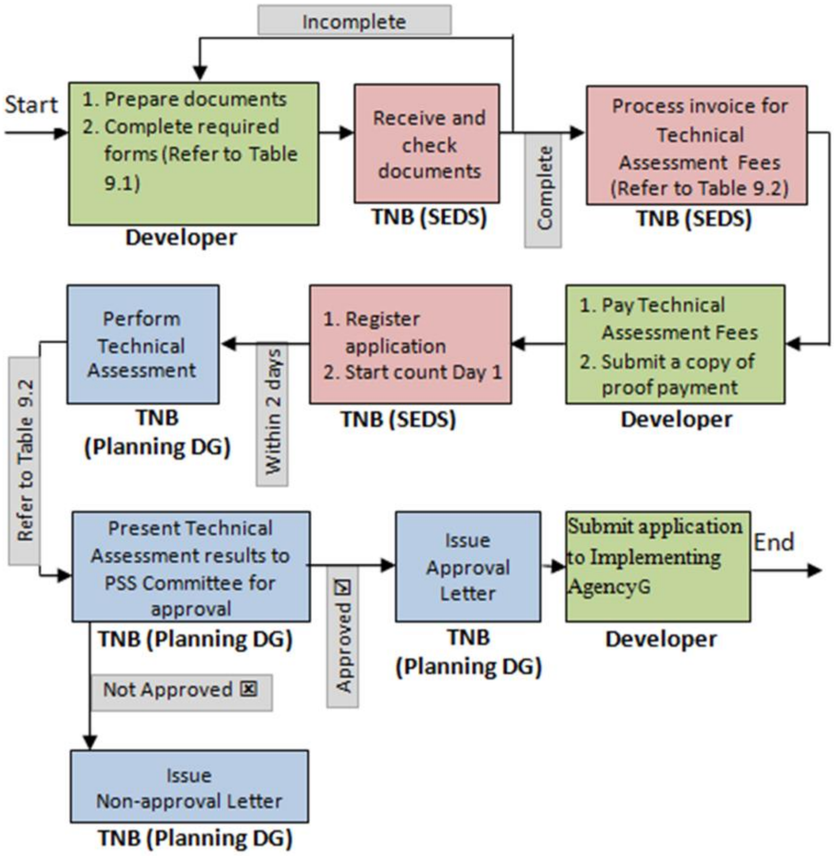


Fig. 9.1: Application Process Flow for NEM and Direct Connection to TNB

DG systems that do not export to TNB, typically facilities that generate electricity for self-consumption or co-generation, shall follow the process flow shown in Fig. 9.2.

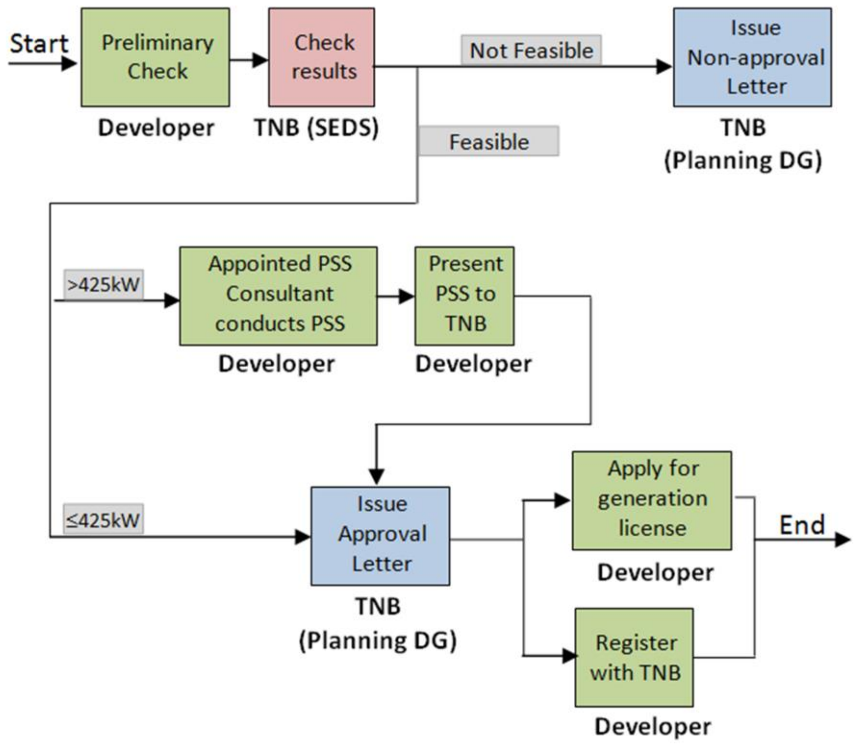


Fig. 9.2 Application Process Flow for Indirect Connection (Selco & COGEN) to TNB.

For DG systems that consist of RE, the forms to be completed will depend on the DG type, DG size and the DG mechanism that the DG system is to be registered under. Please refer to Sustainable Energy Development Section (SEDS), TNB for the latest forms.

Table 9.1 Required forms according to DG Mechanism.

Forms	FIT	LSS	NEDA	NEM	SelCo
Technical Study Application Form	✓	✓	✓		
Form NEM – Technical Study Application			✓	✓	
NEM Application Form (Declaration)			✓	✓	
Borang Permohonan Meter (NEM)			✓	✓	
Borang Pemeriksaan dan Mulatugas (NEM)			✓	✓	
Self-Consumption (SelCo) Registration Form					✓

For DG systems that consist of energy storage, there is currently no application form available therefore applications will be managed on a case-by-case basis.

Table 9.2 Duration and fees for Technical Assessment.

Generation Capacity	Type of Technical Assessment	Duration of study	Fees per Technical Assessment
1-12 kW	No Technical Assessment Required	Not applicable	Not applicable
>12 kW up to 180 kW	CCC/NEMAS	**30 days**	**RM 1000.00**
>180 kW up to 425 kW	CCC/NEMAS	**30 days**	**RM 5000.00**
>425 kW up to 1 MW	NEMAS	**a) 30 days**	**RM 8,000.00**
	PSS	**b) 30 days**	**RM 20,000.00**
	PSS	**c) 60 days** For housing development or individual applications	**RM 500 per installation**
>1 MW up to 10 MW	PSS	**40 days**	**RM 40,000.00**
>10 MW up to 30 MW	PSS	**50 days**	**RM60,000.00**

Source: P.U. (A) 120 Renewable Energy (Technical and Operational Requirements) (Amendment) Rules 2014

9.3 REQUIRED INFORMATION : The information in Table 9.3 is required for the technical assessment:

Table 9.3 Information required for Technical Assessment.

Information Required	DGPV	DGRM	CCCPV	NEM
DG Developer Information	✓	✓	✓	
DG Consumer Information				✓
Type of Application	✓	✓	✓	
Project Location and GPS Coordinate	✓	✓	✓	
Plant General Information	✓	✓	✓	
Registered Electrical Consultant/Wireman Information	✓	✓	✓	✓
Non-solar Generator Information		✓		
Solar PV Installation Information	✓		✓	✓
Step-up Transformer Information	✓	✓		
Technical Self-Assessment				✓

The documents required to be submitted with the application forms are as listed in Table 9.4.

Table 9.4 Documents required for Technical Assessment.

Documents Required	DGPV	DGRM	CCCPV	NEM
Site Plans				
Key Map with nearest TNB substation	✓	✓	✓	
Single line diagram				
SLD for interconnection with TNB	✓	✓	✓	
SLD for DG Plant	✓	optional	✓	✓
Additional Information				
Data for solar radiation	optional			
PV simulation report	optional			
Generator reactive capability chart		✓		
Electricity bill			✓	✓
Photo of existing DL meter and service line				✓
4 days load profiling				✓
Datasheet				
Data sheet for PV Module	✓		✓	
Data sheet for PV Inverter	✓		✓	
Data sheet for Generator		✓		

* All technical drawing(s) must be endorsed by a qualified person.

9.4 SUBMISSION : DG Developer is required to submit application to Distribution Licensee office at:

Sustainable Energy Development Section,
Customer Service Department,
Distribution Division, Tenaga Nasional Berhad,
Level 16,
Wisma TNB,
19 Jalan Timur,
46200 Petaling Jaya,
Selangor

10.0 TESTING & COMMISSIONING	
10.1 TESTING	There are 2 types of testing required: a) Inverter compliance tests b) Interconnection compliance tests <u>Inverter compliance test</u> DG developer is responsible to ensure that the inverter for respective DG unit is in compliance to the TNB requirements. Certified results of tests must be submitted for verification. <u>Interconnection compliance tests</u> Prior to commissioning, the DG plant must be tested to ensure that the performance is up to the required standard, installations are according to the approved scheme, settings are done as approved, etc. Connection of DG plant should not have detrimental impact to the operation of TNB grid. Tests to prove the following items shall be carried out in the commissioning process: a) Anti islanding on loss of mains b) Interlocking scheme c) Equipment functional tests d) Power Quality measurement
10.2 INTEGRATED OPERATION MANUAL (IOM)	Purpose of IOM is to outline duties and responsibilities of both parties at the interconnection between TNB and DG developer. IOM is also to set out the necessary procedures to be followed to ensure safety to the operating personnel and to avoid damage to the equipment at the interconnection point. IOM is jointly prepared by TNB and DG developer representative. IOM has to be completed before commissioning process could be considered.
10.3 POWER QUALITY MEASUREMENT	Power quality background measurements are to be done at the point of connection to ascertain the existing power quality before commissioning. Measurement shall capture the following parameters are: a) 7-day voltage regulation profile b) Total harmonic distortion (THD) voltage c) Unbalanced voltage d) Flicker voltage e) Power and energy measurement (kW, kVAr, power factor) Same measurements are to be repeated after commissioning to identify power quality due to connection of the DG plant.
10.4 COMMISSIONING TEST	Commissioning tests of the installation must be carried out according to the TNB standard commissioning requirements of the relevant equipment.

	The testing of equipment that is to be handed over to TNB, shall be witnessed by TNB personnel. All tests must be carried out by qualified company & individuals. Test equipment must have valid calibration certificate for the results to be accepted by TNB.
10.5 ANTI-ISLANDING TEST	Anti-islanding test reports performed by the manufacturer in the laboratory are to be used as reference. Tests to be done at site are as follows: a. Anti islanding test – as per inverter manufacturer recommendation b. Cease to energize functionality test – to check inverter operation when interface cable is shut off i. Interface cable to be shut off - Outcome expected = No inverter reconnection before time delay lapse ii. Interface cable to switch back on - Outcome expected = Inverter shall only starts to generate again after 2 minutes for LV and 5 minutes for MV. c. Revised setting – Developer shall require to retest any parameter that initially set at factory but has been change at site - Outcome = Inverter operate normally with the new settings (if any) All test results must be certified by the professional engineer.
10.6 RELIABILTY RUN	Under DG Technical and Operational Requirement, all DG plants with MV interconnection are subjected to reliability run. DG developer must prove that the plant not experienced forced outages exceeding 3 times for at least 7 consecutive days to be accepted. The Reliability Run report to be submitted to SEDA by DG developer.

11.0 INTERCONNECTION OPERATION MANUAL

11.1 INTRODUCTION

This Interconnection Operation Manual ("IOM") is a condition precedent as stipulated in Renewable Energy Power Purchase Agreement ("REPPA") between TENAGA NASIONAL BERHAD and DG developer. Both the DG developer and Tenaga Nasional Berhad shall outline in detail their respective duties and responsibilities for the maintenance and operation of the equipment in accordance with the agreed interconnection boundary and subject to the terms and conditions as specified in the IOM.

This chapter summarises the contents of the IOM.

1. The purpose of this IOM is to outline the duties and responsibilities of DG developer and TNB. The IOM also sets out the necessary procedures to be followed to ensure safety to the operating personnel and to avoid equipment damage at the point of interconnection.

2. This IOM contains the entire document and understanding of the Parties with respect to the subject matter identified as recitals, introduction, interconnection facilities, communication, switching procedures, fault reporting, outage program, system emergency / collapse, definitions and appendices.

3. This IOM shall be revised and when necessary according to any changes of operating personnel or other relevant operating conditions affecting the Parties. Any changes to the IOM must be agreed by the Parties.

4. Not withstanding anything in this IOM, TNB shall ensure that requirements under the existing TNB Supply Rules, Technical Instruction, Engineering Instructions, System Operation Manual, TNB Safety Rules or the compliance of the Act and Prudent Utility Practice are satisfied. In the event of any inconsistency or ambiguity between IOM and the requirements listed above, the requirements listed above shall prevail over IOM.

5. Not withstanding anything in this IOM, DG developer shall ensure that requirements under the existing DG developer's Safety Rule Book and / or the recommended Operating and Maintenance Instructions provided by the equipment manufacturer or compliance of the Act and Prudent Utility Practice are satisfied. In the event of any inconsistency or ambiguity between IOM and the requirements listed above, the requirements listed above shall prevail over IOM.

6. Neither party shall be liable to the other for any claims, judgments, liabilities, losses, cost, expenses or damages of any kind of character (including loss of property) which are the consequence of damage to or destruction of property or personal injury (including death) resulting from the

performance of this IOM unless the damage, destruction or injury arises out of or caused by the negligence, default, misconduct of a Party’s own employees, officers, agents, contractors or subcontractors.

7. The Parties shall indemnify and hold the other party, its officers, directors, employees, contractors and subcontractors, agents, harmless from and against any and all claims, losses, liabilities, cost, expenses and damages of any nature whatsoever for personal injury, death or property damage except to the extent such injury, death or damage attributable to the negligence, willful act or default of the party seeking indemnification herein mentioned.

8. Each Party shall designate in writing to the other Party a representative, who shall be authorized to resolve any dispute, controversy or claims arising out of or in relation to this IOM. The Parties hereby agree to attempt to resolve all disputes, controversy, claims, breach, termination or validity thereof arising under this IOM promptly, equitably and in a good faith manner.

9. All operations and technical matters shall be communicated, discussed and resolved solely between TNB and DG developer.

10. This IOM shall be binding and complied with by the Parties.

11.2 INTERCONNECTION FACILITIES	This section describes the responsibilities of each party at the interconnection boundary with the aim to achieve safe, efficient and timely operation at all times.
11.3 COMMUNICATION	This section describes the communication protocol between both parties during operation hours and emergency condition.
11.4 SWITCHING PROCEDURE	This section describes the switching procedure of TNB VCB at Interconnection point and at DG developer's sub-station. Prior to switching the Parties shall agree to the purpose of the intended action which to be recorded in the station log book accurately at DG developer's sub-station. Detail of all initial conditions of protection relays, line isolators, circuit breakers or other relevant indicators at the sending and receiving sub-stations shall be disclosed accurately to the Parties. When works need to be carried out on TNB VCB at the interconnection point, proper isolation and earthing shall be established.
11.5 FAULT REPORTING	This section describes the procedures for fault reporting. 1. In the event of a fault or incident which has operational impact to the installations to the Parties, a written report shall be submitted by the party concerned. However, if a fault occurs which has affected the normal operation of the interconnection, such fault shall be recorded by DG developer and reported (written) to TNB or vice-versa. 2. During normal operation, TNB shall inform DG developer if TNB intends to carry out an operation that will impact DG developer's operation. Similarly DG developer shall also inform TNB if DG developer intends to carry out an operation that may affect TNB system. 3. Any notification given by either party shall have sufficient detail to enable the receiving party to make necessary arrangement from such notification. In case of doubt either party shall have the right to seek further clarification to satisfy his concerns. All reports shall be extended to TNB office and DG developer. 4. In the event of any fault, the Parties shall use its best endeavor to rectify the fault and / or minimize system disruption at the shortest possible time. 5. Any conclusion resulting from any incident investigation shall be shared by the Parties.
11.6 OUTAGE PROGRAM: SCHEDULED AND UNSCHEDULED	This section describes the program for scheduled and unscheduled outages.

1. The scheduled outages are planned outages for maintenance, overhaul, major repair works, new supply project or system improvement project. The unscheduled outages are the forced outages mainly due to tripping or outages for repair.

2. The maintenance schedule for the Parties shall be coordinated to minimize system downtime.

3. The Parties shall use its best endeavor to carry out the maintenance program on its protective relays, circuit breakers, transformers, earth switches, isolators, etc. in conjunction with the other party maintenance program as practically possible.

   Each party shall use its best endeavor to notify the other for planned outages with at least seven (7) days notice. In the event of unscheduled request, immediate notification shall be issue by the Parties.

4. The Parties shall undertake to carry out work using safe working procedures.

5. Interconnection / inter tripping facilities shall be under DG developer and tested by Parties based on the agreed schedule. There will be four (4) minimal interlocking between TNB and DG site which are:-
   - A open --> B to open
   - A open --> B cannot close
   - B close --> A cannot close
   - Earth switch B on --> A cannot close

   Note: A = TNB VCB at Interconnection point
   B = VCB at DG developer's sub-station or HT P/E

6. In the event of synchronizing Control Board malfunction (protection, control and loss of power supply), disconnection of supply shall be done at DG developer's side.

7. DG developer's anti-islanding protection must operate in less than 2 seconds in the event of loss of main from TNB grid. The reconnection time shall be Five (5) minutes after normalized.

8. Manual operation of TNB VCB at Interconnection point and VCB at DG developer's sub-station or HT P/E is not allowed.

11.7 UNSCHEDULED OUTAGES: SYSTEM EMERGENCIES / COLLAPSE	1.	In the event that there is a major system disturbance, where there is a complete loss of supply due to tripping, TNB shall expeditiously take all necessary steps to normalize supply. DG developer shall use its best endeavor to make contact with TNB and when the necessary communication could not be established, TNB shall allow DG developer to control and operate the 11kV system within the power plant as the stated event in the table below. DG developer shall be responsible to inform TNB immediately after the switching is completed.
	2.	The Parties shall confirm the supply system is restored to enable DG developer to proceed re-energizing the DG Generation System. The Parties shall liaise with each other regarding the circuit condition after service is normalized.
	3.	Wherever a condition develops which is considered dangerous to working personnel and / or increase risk of damage to property, emergency switching can be carried out immediately by DG developer / TNB authorized personnel. They shall use their best endeavor to inform the other party immediately.
	4.	During loss of mains supply, DG developer's anti islanding protection shall operate in less than 2 seconds to isolate DG system from the grid. The anti-islanding protection detection expected shall be voltage, frequency, Rate of Change of Frequency (ROCOF) and Voltage Vector Shift Detection.
11.8 SEQUENCE OF OPERATION FOR 11KV SYSTEM	This section describes the sequence of operation and maintenance at TNB's interconnection sub-station for the following: a) 11 kV TNB Feeder VCB protection at TNB Interconnection Sub-station b) 11 kV TNB Feeder VCB controls at TNB Interconnection Sub-station c) Proposed Sequence Of Operation (Emergency Operation) d) Maintenance & Fault location of 11 kV power cable and fibre optic cables e) Maintenance of Unit protection and interlocking scheme f) Maintenance of OC/EF with reverse power relay function	
11.9 OPERATION AND SAFETY	For purposes of safety coordination procedure, the following requirements are prerequisites:	

REQUIREMENTS

a) At each point of interface/connection between the distribution system and the PV Plant, the boundary of ownership is clearly defined;
b) The Distributor and the PV Operator provide each other with the operating diagrams of their respective side of the point of interface/connection;
c) The Distributor and the PV Operator must exchange information on safety rules and / or instruction as practiced in their respective system.

All switching operations shall be carried out according to the procedures as defined in the Standardized Distributor's Safety Rules (TNB Safety Rules), which shall include but not limited to the following:

a) Coordination;
b) Isolation/ Islanding;
c) Earthing;
d) Recording;
e) Testing;
f) Commissioning;
g) Cancellation; and
h) Reenergizing.

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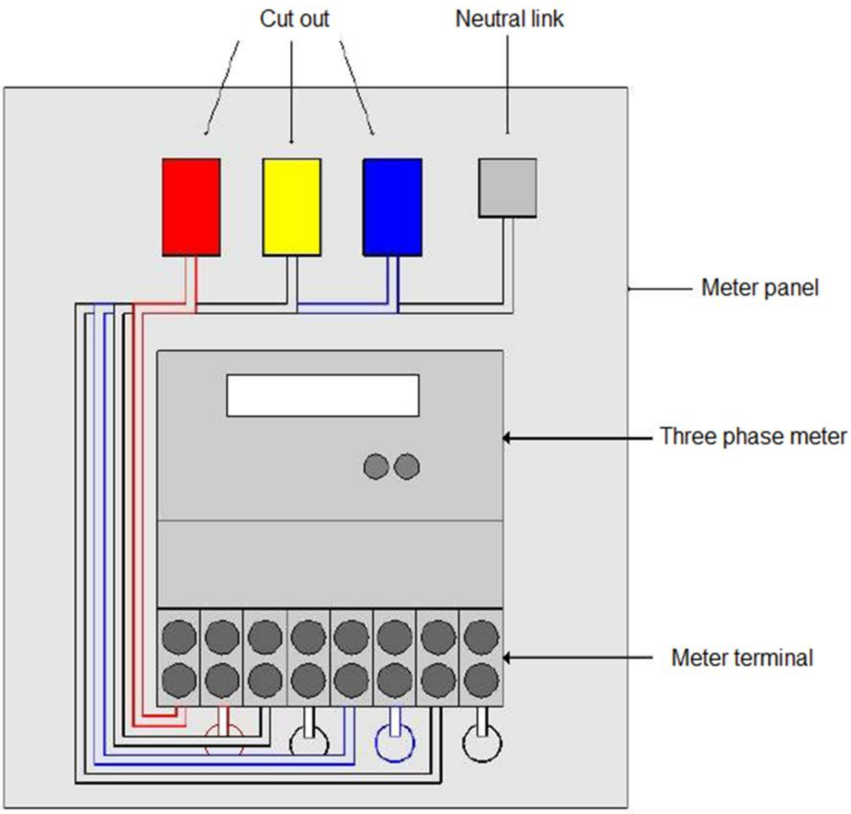
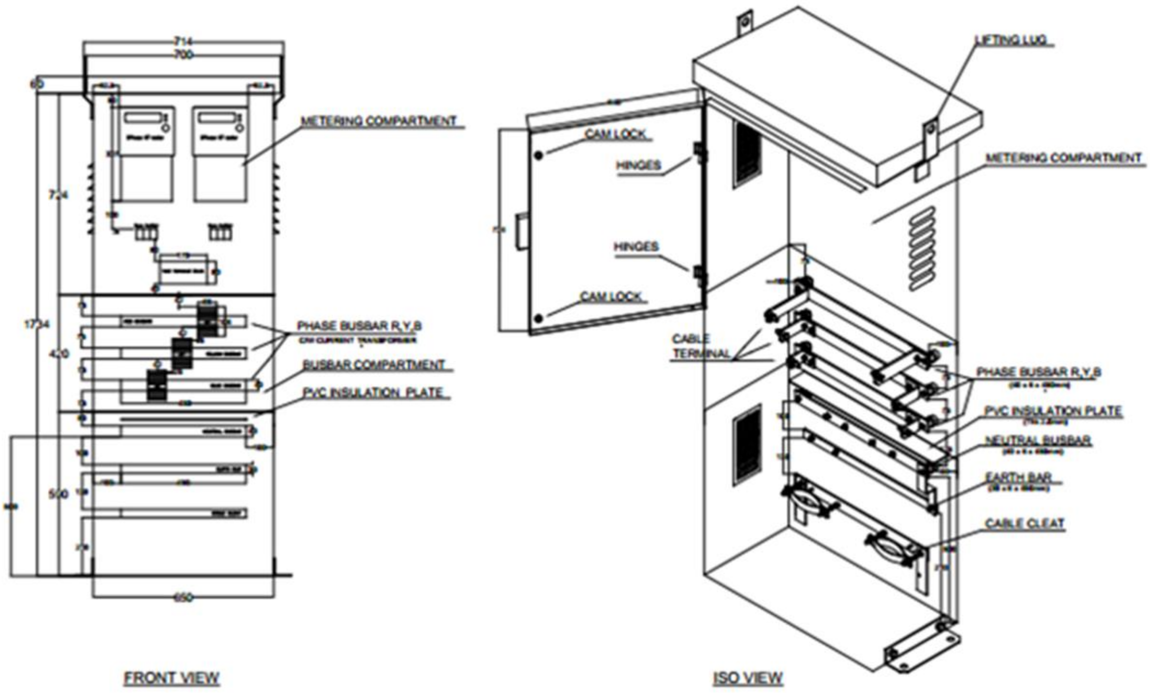
APPENDICES

APPENDIX A: LAYOUT OF THREE PHASE WHOLE CURRENT LV METERING PANEL



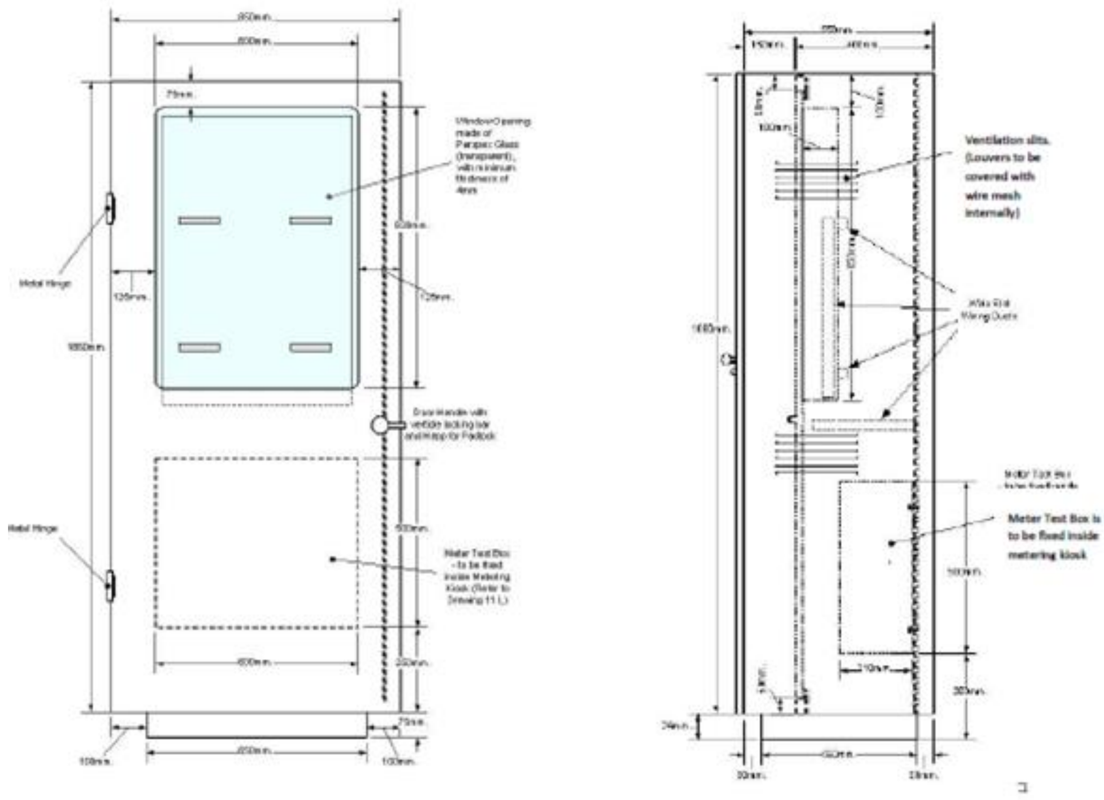
APPENDIX B: LAYOUT OF LVCT METERING PANEL



About	Specification (400/800/1600A)
IEC Standard	• IEC 61439-1:2011 • IEC 61439-5:2006 • IEC 60947-1:2007 +A2:2014 • BS EN ISO 17834:2003 • IEC 60529:1989 +A1:1999+A2:2013
Approved type test certificates	• Short circuit test report • Temperature rise test report • IP 33 test report
Busbar Configuration	• For 400A type, the busbar dimension must be minimum and equivalent to 30 mm x 8 mm • For 800A type, the busbar dimension must be minimum and equivalent to 38mm x 10 mm • For 1600A type, the busbar dimension must be minimum and equivalent to 80mm x 10 mm • Additional busbar for earthing and neutral • Dedicated L-Shape bar at incoming side of the busbar of each phases
Mounting	• All installation CT shall be mounted on the TNB Meter Kiosk before consumer incomer (Outdoor Substation TNB or Meter Room). • The metering kiosk enclosure's back plate shall be riveted using mono bolts made of stainless steel Grade 304 • Circuit identification labels, incoming and outgoing identification labels, S1 and S2 terminal for TNB CT identification labels

Antenna Hole	• The enclosure shall be able to accommodate a hole for Antenna Ariel of the metering modem to be installed from inside at the top and extended to outside the metering kiosk
Cable Termination, Clamp and Support	• Cable supports shall be provided by suitable clamps • Cable termination arrangements shall be located at the lowest point of the metering kiosk • Distance from the floor to the cable clamp - 200 mm • Distance from the cable clamp to the neutral bar - 400 mm
Cleaning and Painting	• Cleaning process shall follow the Electro Galvanizing Process and the application of paint • The non-stick paint shall be applied from TNB approved list • Maintain all quality records of the finishing coat for a minimum period of Five (5) years
Inspection & Work Test	• The specification shall be subject to inspection and tests during manufacture and on completion by the Purchaser or his representatives • Inspection and tests shall generally comprise: a) Temperature rise test on one sample before the first delivery. b) Dimensional and alignment checks on component parts. c) Sample assemblies of complete metering kiosk. d) High voltage tests, 2.5 kV A.C. for 1 minute. e) Sample tests on materials, if and when considered necessary by the Purchaser or his representatives
Nameplate	• Metering Kiosk shall be provided with a nameplate and marked as follows : a) The manufacturer's name or trademark; b) TNB contract number; c) Delivery month and year; d) Rated operational voltages; e) Rated short-time withstands current
Packing	• All equipment shall be so packed as to provide adequate protection against damage during storage and transportation

APPENDIX C: TYPICAL MV METERING KIOSK



Please refer to latest TNB Electricity Supply Application Handbook for full details of metering kiosk

APPENDIX D: TECHNICAL STUDY APPLICATION FORM
(Please refer to Sustainable Energy Development Section, TNB for the latest forms)

FORM – TECHNICAL STUDY APPLICATION

For connection of renewable energy power plant to TNB

This form must be completed by the appointed Electrical Consultant Engineer registered with the Board of Engineers Malaysia. For guidance on completing this form, please refer to the corresponding instructions.

IMPORTANT: All fields are mandatory unless indicated otherwise. All the details on this form must be completed. An incomplete forms and supporting documents will be returned which may delay the process.

Please print and return the forms to TNB to the following address:

- Post: General Manager (Sustainable Energy Development Section),
  Customer Service Department,
  Level 16,
  Wisma TNB,
  19 Jalan Timur,
  46200 Petaling Jaya,
  Selangor
- Fax: 03-7960 0348

If you have any questions please e-mail: RE@tnb.com.my

Payment of the required fees must be received by TNB before the process begins.

Note:

Indirect Connection:

a. Default connection scheme for all connection is direct connection unless justified and verified during site visit, subject to TNB approval and T&O 2011 rules.
b. A special supply agreement is required for the power consumed by the RE Plant.
c. All requirements specified in T&O 2011 rules and guidelines must be complied.

All technical drawing(s) must be endorsed by a qualified person:

1. Endorsed by PE (Electrical)
2. Endorsed by wireman(<72kWp)

No payment will be accepted until all the complete technical data are received and preliminary capacity check is completed.

Technical study will be conducted once we receive proof of payment. The study will include site visit, which will be arranged by TNB with the respective area and developer. Developer is advised to send a competent person to attend the site visit.

Abbreviation:

TNB: Tenaga Nasional Berhad
T&O: Technical and Operational
PE: Professional Engineer

FORM : **TECHNICAL STUDY APPLICATION**

For Connection of Renewable Energy Power Plant to TNB

Received date : ______________

TNB Ref. No : ______________

SECTION A : RE DEVELOPER INFORMATION

1. Developer Name : ______________ 2. Co. Reg No. / IC No. : ______________
3. Postal Address : ______________
4. Telephone (Office) : ______________ 5. Fax : ______________
6. Person in-charge : ______________ 7. Position : ______________
8. H/phone : ______________ 9. Email Address : ______________

SECTION B : TYPE OF APPLICATION

1. Application:
☐ New application
☐ Additional application
i) Approved Capacity:______________kW
ii) TNB Ref. No: ________________

2. Type of Study:
☐ Connection Confirmation Check (CCC) <= 425 kW
☐ Power System Study (PSS) >425kW

SECTION C : PROJECT LOCATION

1. Installation address : ______________

2. Global Positioning System (GPS) co-ordinates :

i) Longitude : ______________ N ii) Latitude : ______________ E

SECTION D : PLANT GENERAL INFORMATION

1. Type of Plant:	2. Net Export Capacity:		3. Expected Annual Energy Generation
☐ Solar	____________kWp	____________kWac	____________kWh/year
☐ Biogas	____________kW		____________kWh/year
☐ Biomass	____________kW		____________kWh/year
☐ Mini Hydro	____________kW		____________kWh/year
☐ Others:______________	____________kW		____________kWh/year

SECTION E : REGISTERED ELECTRICAL CONSULTANT / WIREMAN INFORMATION [1]

1. Company Name : ______________
2. Telephone (Office) : ______________ 3. Fax : ______________
4. Person in-charge : ______________ 5. Position : ______________
6. H/phone : ______________ 7. Email Address : ______________

Technical Study Application

SECTION F: DETAIL INSTALLATION INFORMATION

PART 1: NON-SOLAR GENERATOR INFORMATION

a) Generator type : ☐ Synchronous ☐ Induction ☐ Other : ___________________

b) Rating : __________________ kVA @ __________________ p.f

c) Rated Terminal Voltage : __________________ kV

d) Frequency : __________________ Hz

e) Minimum p.f. lagging : __________________ f) Minimum p.f. leading : ______________

g) Type of Control : ☐ Voltage Control ☐ Power Factor Control

h) Generator Sub-Transient Reactance : ____________ p.u i) Generator Transient Reactance : ______________ p.u

PART 2: SOLAR PV INSTALLATION INFORMATION

a) PV Module i) Type : ____

(monocrystalline, polycrystalline, thin film etc.)

b) Inverter i) Number of inverter installed : _______________nos

ii) Type : ☐ Centralised ☐ String

iii) Manufacturer : _________________________________

iv) Power Factor : ☐ ______lagging ☐ unity ☐ _______leading

PART 3: STEP-UP TRANSFORMER (SOLAR & NON-SOLAR)

Note: *If multiple transformers used, please include transformer details sheet for each transformer.*

a) Rated Capacity : _________________ MVA b) Voltage Ratio (HV/LV) : _________/_________

c) Tap range : _________________ (min) d) Vector Group (HV/LV) : _________/_________

: _________________ (max)

e) Tap Step : _________________ f) Impedance : __________________ %

g) Method of Earthing : _________________ h) Resistance : __________________ p.u

Technical Study Application

SECTION G: CHECKLIST OF REQUIRED DOCUMENTS

	Please (√)
a) Site plans key map with nearest TNB substation *(Please label the substation name)* or proposed connection point (eg: feeder pillar/overhead lines/existing meter)	☐
b) Single line diagram of any existing or proposed arrangements of the interface connection between TNB & RE plant[1]	☐
c) Generator reactive capability chart (non-Solar)	☐
d) Generator Datasheet (non-Solar)	☐
e) Data Sheet for PV Module (Solar only)	☐
f) Data Sheet for Inverter (Solar only)	☐
g) Single Line Diagram of Solar PV installation (Solar only)	☐
h) Electricity bill (if applicable)	☐

SECTION H: CONFIRMATION

By signing this form, I declare that the information provided is true to the best of my knowledge and belief.

Prepared by : ______________________ PE (Electrical) stamp / Wireman (<72kW):

Signature : ______________________

Date : ______________________

APPENDIX E: FORM NEM – TECHNICAL STUDY APPLICATION
(Please refer to Sustainable Energy Development Section, TNB for the latest forms)

FORM NEM – TECHNICAL STUDY APPLICATION

PART 1: INFORMATION

- Customers may not operate their Solar Photovoltaic (PV) system while interconnected to the DL Distribution System until they receive written permission from the Authority
- For solar PV system more than 72kW customer need to apply for generating license from Suruhanjaya Tenaga (ST)

PART 2: CONSUMER INFORMATION – to be filled by the Registered Customer

Applicant Name:____ IC/ROC Number: _______________________

Electricity Bill account number:_______________________________

I hereby authorize the Competent Person as described in PART 3 to act on my behalf to manage my NEM application

Signature: Date:

PART 3: COMPETENT PERSON (SERVICE PROVIDER/CONTRACTOR) DETAILS

Name:____ Company ROC No. :___________________________

Phone Number: _______________________________ E-mail address: ______________________________

Mailing Address:____

PART 4: CONSUMER INFORMATION

Installation Address: ____

Is the applicant an existing FIAH? : ☐ Yes ☐ No If yes, please provide the existing solar capacity installed(kW) ________________

Voltage at point of common coupling: @TNB meter ☐ Low Voltage (230V/400V) ☐ Medium Voltage (11kV/33kV)

TNB Substation name: __________________________________

If Medium Voltage connected customer: Maximum Demand ________________kW
If Low Voltage connected customer : Fuse Rating: ____________(Amps) or CT rating:___________________

Reasons for installing NEM ☐ Reduce electricity bill ☐ Peak Shaving ☐ Reduce Green House effect Other reasons:_______________________

PART 5: TECHNICAL SELF ASSESSMENT

a) Installed NEM PV Capacity ______________in kW_p b) ____________________in kW_{ac}

c) Estimated Monthly Generation:__________kWh d) Distributed Annual Availability Data (DAA):_________kWh

e) Expected Date of Commissioning of NEM solar system: _____________________(dd/mm/yyyy)

f) Installation of Battery Energy Storage System: ☐ Yes ☐ No If yes, Battery capacity __________ kW

Battery Manufacturer:________________

Information below is only for generation capacity >12kW. Competent Person shall fill in and attach the Load Profile (LP) Form

g) Daytime Peak Demand (11am to 3pm)___________kW (Friday to Monday)

h) Daytime Lowest Demand ______________kW i) Export during daytime peak (b-g) ___________kW_{ac}

j) Export during daytime lowest (b-h) ____________kW_{ac}

PART 6: PHOTOVOLTAIC (PV) INSTALLATION INFORMATION

a) PV Module : i) Type: Monocrystalline ☐ Polycrystalline ☐ Thin Film ☐ Others:_______________

: ii) Manufacturer ________________________________

b) PV Inverter i) Number of inverter installed __________________________

ii) Type: Single Phase ☐ Three Phase ☐

iii) Manufacturer _____________________

iv) Power Factor: ☐ __________ lagging ☐ ______________ leading ☐ unity

PART 7: CHECKLIST OF DOCUMENTS REQUIRED

i.	Single line diagram with Solar PV schematic(endorsed by Competent Person)	☐
ii.	Photo of existing DL meter and service line	☐
iii.	4 days Load profiling (Friday to Monday for capacity >12kW)Form LP	☐
iv.	A copy of electricity bill (latest)	☐
v.	CD (contains) all of the above documents saved under 1 pdf file <3MB	☐

PART 8: DECLARATION

By signing this form, I declare that:

- I am representing the owner of the premise and the information furnished above is true to my knowledge and belief.
- I confirm that the solar PV system design comply to the standards (IEEE 1547, IEC 61727, MS 1837,NEM Technical Guideline) and the inverter (s) used are as per approved lists.
- I also verify that the site condition is fit for installation of the solar PV system as per applicable regulations.

Signature : Competent Person stamp:

Name:

Date:

PART 9: FOR OFFICE USE

APPENDIX F: NEM APPLICATION FORM – DECLARATION
(Please refer to Sustainable Energy Development Section, TNB for the latest forms)

TENAGA NASIONAL BERHAD

NET ENERGY METERING (NEM) APPLICATION FORM

PART 1: CONSUMER INFORMATION

Name of Consumer : ____

TNB Account Number : ____

Installation Address : ____

____

____

Contact Number : H/P____________________ Home__________________

Email : ____

NEM Application Number :

PART 2: NEM SOLAR PV SYSTEM INFORMATION

Total Generation Capacity : ____________________kW

Commissioning Date of NEM Solar PV System : ____________________(dd/mm/yyyy)

NEM Solar PV System Comply with the Following Standards :
- IEEE 1547 ☐
- IEC 61727 ☐
- MS 1837 ☐
- : NEM Technical Guideline ☐

Inverter Manufacturer : ____________________

Inverter rating : ____________________kW

Number of Phases : ☐ Single Phase ☐ Three Phase

PART 3: COMPETENT PERSON/SERVICE PROVIDER DECLARATION

I declare that:

- I am representing the owner of the premise and the information furnished above is true to my knowledge and belief.
- I confirm that the solar PV system design comply to the standards (IEEE 1547, IEC 61727, MS 1837) and the inverter (s) used are as per approved lists.
- I also verify that the site condition is fit for installation of the solar PV system as per applicable regulations.
- I hereby acknowledge that all information given are true and the relevant Authority shall have the right to take any action if the above information are false.
- I attached the Testing and Commissioning (T&C) form as evidence that all required T&C has been done.
- I enclose a valid G & H forms to which the NEM solar PV installation is attached or wired for the electricity supply.
- I enclose pictures of the new meter reading taken on the same day of signing of this Contract.

Name:

____________________________ Designation:

Competent Person/Professional Engineer/
Service Provider Signature IC No:

PART 4: NEM CONSUMER'S DECLARATION

I hereby declare that the information provided in the Form A (SEDA's NEM application form) and this TNB's NEM application form is true to the best of my knowledge and belief. In case any of the above is found to be false, I am aware that TNB has the right to reject/terminate/cancel my application and forfeit my application fees. I further agree to comply with the specifications, terms and conditions stipulated in the applicable guidelines and related regulations by TNB and EC, as amended from time to time. I also confirm that I have read and understood the NEM Contract for the connection of NEM solar PV installation and agree to abide by them.

______________________________ Name:

NEM Consumer's Signature IC No:

PART 5: FOR OFFICE USE ONLY

____

TNB Executive's signature

Staff No:

Designation:

APPENDIX G: NEM APPLICATION FORM
(Please refer to Sustainable Energy Development Section, TNB for the latest forms)

TENAGA NASIONAL BERHAD — **BORANG PERMOHONAN METER (NEM)** | Tarikh Terima:

BAHAGIAN 1 : MAKLUMAT KONTRAKTOR ELEKTRIK / SERVICE PROVIDER

KONTRAKTOR ELEKTRIK / SERVICE PROVIDER : ______________________

NO. KAD PENGENALAN / NO. SYARIKAT : ______________________

ALAMAT KONTRAKTOR ELEKTRIK / SERVICE PROVIDER : ______________________

NO. FAKS : ____________ EMAIL : ____________

NO. TEL PEJABAT / BIMBIT : ____________

BAHAGIAN 2 : MAKLUMAT TEKNIKAL

PARAS VOLTAN PENYAMBUNGAN : ☐ 240V ☐ 415V ☐ 11kV ☐ 33kV

KAPASITI (kW) : ____________ ☐ Direct ☐ Indirect

CADANGAN TARIKH MULA TUGAS : ______________________

BAHAGIAN 3 : MAKLUMAT PEMOHON NEM

NAMA PEMOHON : ______________________

NO. KAD PENGENALAN PEMOHON : ______________________

E-MAIL PEMOHON : ______________________

NO. SIJIL NEM : ☐☐☐☐☐☐☐☐☐☐☐☐ NO. AKAUN BIL ELEKTRIK : ☐☐☐☐☐☐☐☐☐☐☐☐

NO. SIJIL GST : ☐☐☐☐☐☐☐☐☐☐☐☐ TARIKH KUATKUASA GST : ☐☐☐☐☐☐☐☐

BAHAGIAN 4 : DOKUMEN YANG PERLU DIMAJUKAN OLEH PEMOHON

SENARAI SEMAK :

- ☐ Salinan Sijil NEM
- ☐ Gambar pepasangan meter sediada beserta talian serbis
- ☐ Gambar cadangan lokasi meter sekiranya terdapat perubahan pada lokasi meter sediaada
- ☐ Salinan sijil GST (sekiranya berkaitan)

Saya / Kami dengan ini memberi pengakuan bahawa makluman yang diberikan adalah benar.

* ______________________

** Perlu dicop dan ditandatangan oleh Pemohon/ Kontraktor Elektrik/Service Provider*

** Sila majukan borang permohonan ini kepada TNB Zon*

KEGUNAAN PEJABAT

☐ Dokumen Lengkap

☐ Ya ☐ Tidak

Nama Pegawai Penerima

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APPENDIX H: TESTING AND COMMISSIONING FORM – NEM
(Please refer to Sustainable Energy Development Section, TNB for the latest forms)

TENAGA NASIONAL BERHAD

BORANG PEMERIKSAAN DAN MULATUGAS (T&C) NET ENERGY METERING (NEM) (OPC & LPC)

NAMA PELANGGAN:	TARIKH PEMERIKSAAN:
NO AKAUN:	JAM MULA:
ALAMAT PREMIS:	JAM TAMAT:

MAKLUMAT TEKNIKAL PERPASANGAN SOLAR PV

Voltan pada titik sambungan (sebelum perpasangan) *Voltage at Point of Connection (before installation)*	RED: Volts	YELLOW: Volts	BLUE: Volts
Voltan pada titik sambungan (selepas perpasangan) *Voltage at Point of Connection (after installation)*	RED: Volts	YELLOW: Volts	BLUE: Volts
Voltan pada Meter TNB (sekiranya boleh diakses) *Voltage at TNB meter (if accessible)*	RED: Volts	YELLOW: Volts	BLUE: Volts
Anti-islanding Test	Disconnection Time: sec Reconnection Time: min		

PENGESAHAN PENGUJIAN DAN MULATUGAS SISTEM SOLAR PV OLEH ORANG KOMPETEN

Tandatangan: Nama: No I/C: Tarikh:	Cop Syarikat: