TECHNICAL ISSUES ON DISTRIBUTED GENERATION (DG) CONNECTION AND GUIDELINES

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ABSTRACT

The promotion of combined heat and power or cogeneration for energy efficiency and introduction of renewable energy (RE) as the fifth fuel by the Malaysian Government have resulted in the increasing number of applications of distributed generation connection to TNB's distribution network.

The lack of common industry guidelines has led to TNB developing its own "Technical Guidebook for Connection of Generation to Distribution Network" based upon the growing body of knowledge, inputs from foreign consultants and solicited feedback from developers, consultants, academicians and operators of RE/DG plants.

The paper discusses the guidelines and recommendations of the guidebook on various technical issues encompassing capacity adequacy, network losses, voltage regulation and control, fault level, protection, interface design, operational safety, system stability, etc. to ensure that system reliability, safety and efficiency is not negatively impacted following the connection of a distributed generation.

It is critical for the guidebook to provide clear and unambiguous technical guidelines to key stakeholders of the electricity supply industry for the long-term growth, development and success of distributed generation in the country.

INTRODUCTION

The promotion of energy efficiency and renewable energy resources by the Malaysian government have contributed to an increasing number of distributed generation (DG) connection applications [1]. Most of these applications are from developers of renewable energy, mainly mini-hydro & Biomass (Palm Oil Waste) and industrial customers, who are migrating to cogeneration for energy efficiency.

Although the level of DG penetration is not high, approximately 1% of maximum demand, DG connection and operation in parallel with TNB distribution system would create various technical issues [2] & [3] that must be recognized and addressed before it could be connected.

In view of these technical issues and with some earlier experiences of DG connections, TNB has recently published a revised official guidebook for the connection of distributed generation entitled 'Technical Guidebook for the Connection of Generation to the Distribution Network' [4].

The Guidebook has been developed based on solicited feedback from stakeholders of the local electricity industry through workshops and meeting as well as inputs from foreign consultants and other international publications.

OVERVIEW OF CONNECTION ISSUES AND RECOMMENDATIONS

Distribution systems, which are passive in nature have not been designed to accommodate generators. Therefore, any connection of DG would lead to technical issues and the Guidebook has been designed to provide guidance and recommendations on all technical aspects of DG connection from planning, design and operation.

Network Voltage Control

Voltage control is normally done using transformers' On-Load- Tap-Changer at Transmission substations or Main/Large Distribution substations.

A synchronous generator embedded in the distribution network would normally be equipped with an automatic voltage regulator (AVR) capable of controlling the voltage or the VAr output at the generator terminal. This is performed by the AVR through regulating DC excitation current to the generator field circuit.

Operationally, power factor control is practiced and unity power factor is adopted. Nevertheless, using power factor control may cause problem of system voltages exceeding regulated limits particularly during light load condition.

As such, the choice of control modes will be subject to the 'Preliminary System Study' to be carried out by TNB. The Guidebook provides the advantages and disadvantages of the various controls options i.e. power factor, voltage or VAr controls.

Fault Levels

Synchronous generators contribute fault currents in response to faults in the network. When a generator is connected, the prospective short circuit or fault level will increase due to the fault current contribution. The rise in the prospective fault level is limited by the system capability to withstand the potential fault current. This limit is the equipment capability of switchgear and cables.

The Guidebook stipulates the critical limit for fault level with DG connection is not to exceed 90% of equipment short time rating. It also provides several mitigating measures to reduce generator's fault current contribution such as increase generator impedance, use of reactor, network splitting, current limiters, etc. The 10% safety margin is for consideration of probable error in network data.

Network Adequacy

The Guidebook specifies that Distribution system would normally have interconnecting feeders with open points. Under contingency or maintenance when one section is on outage switching operation would be carried out to restore supply. As such, adequacy of circuit capacities must then be assessed under both normal and contingency conditions.

Also, a generator will tend to unload the feeder between it and the main intake substation, but will have no effect between the generator and the end of the feeder. This will depend on the generator output in relation to the existing demand. Generator export exceeding existing feeder demand current flow and the use of shunt reactor may overload certain segments of the feeder between the generator and the main intake substation (See Figure 1). Feeder loading situation must also be assessed to cover the future years.

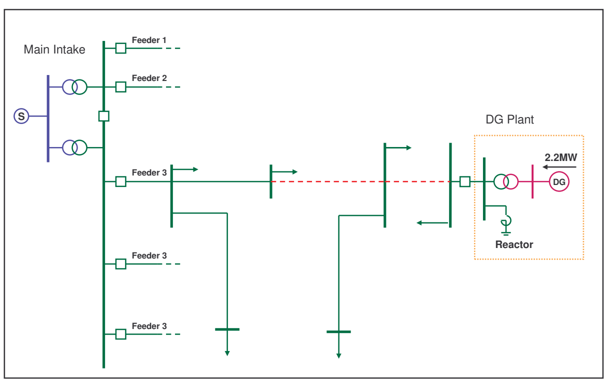

Figure 1: Feeder segments overload with DG

Power Quality

Harmonics can generally be a problem when using semiconductor devices such as converters within networks. Very high harmonic levels are associated with the use of converters in smelting works. Careful monitoring of harmonic level necessary where a number of these devices are used in the network. Generators and transformers can dissipate harmonics currents; however, it will cause over-heating. Information on Total Harmonic Distortions (THD) is available on request.

Flicker is not currently a problem with the levels of generation connected to distribution system. However, with increasing generation connections and different generation technology, interactions between generation and incorrect control settings could cause flicker. Power System Stabilizers (PSS) installed in Generator excitation systems can be used to control flicker. It should be noted that studies will be required to obtain the correct settings for PSS.

Protection Schemes and Controls

Protection systems are essential for both the network and the generator to ensure safe operation. Network and generator protection systems do interact and will need to be designed to co-ordinate with each other. TNB is responsible for design and operation of the network systems, whilst the DG Developer is responsible for design and operation of the Generator systems. At a stage in the generation project, an interchange of information is essential to enable each system is designed to be coordinated.

The design of the network protection systems is based on TNB's Protection and Control Code of Practice. All equipment to be used to be interconnected to TNB must be approved by TNB. This is required to ensure design and plant consistency across the network.

Generator connections and generator protection systems should be designed to prudent utility practice and conform to current safety and regulatory standards. The followings should also be taken into account when designing generator protection systems.

- _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.
- _Fault clearance time for generator faults_ – There are a number of faults within the generator systems that could affect the stability of Distribution Networks. 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.
- _Unit protection for connection cables_ – It has been the practice of TNB 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, TNB will consider directional current protection.
- _Other requirements_ - Pole slipping protection could self-protected generators from system instability and may be required as identified by stability studies.
- _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.
- _Distribution Network Back-up fault clearance_ - Network backup fault clearance can take up to a maximum of 1.2 seconds at the source. Developers will need to take this into account when designing protection systems.

Losses

Generators do have a significant effect on network losses; it can lower or increase losses depending on its location and the network configuration. In principle, when a generator is connected to a distribution system, there should not be any increase in losses in comparison to the system without the generator

Connecting generators at a higher voltage and/or at a different location can normally reduce losses. Location can be important because losses can only be reduced if the generator can back-off demand. Essentially, losses are reduced by connecting a generator in high demand areas.

When designing a generator connection, the effect on losses needs to be taken into consideration. In most cases, there will be an opportunity to reduce system losses and maximize the benefits brought about by the generator and can only be analysed through examination of various network operating conditions.

Losses are calculated by carrying out load flow studies on the system. Procedures for carrying out the studies are described in the Guidebook. Where practical, the methodology for carrying out the studies and assumptions should be made transparent to the DG Developer.

Stability

Generator transient instability is not normally an issue with generators connected to a distribution system. However, 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 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 network caused by other generators in the system.

Interface Design

Many technical issues described above could be resolved and addressed by having a appropriate interface design. However, there are technical issues that cannot be addressed at the interface but may have to be incorporated in the plant at the design stage.

The Guidebook recommends the use of interface transformer as one of the vital interface design requirements (Refer Figure 2). The advantages of using interface transformer include;

1) Ensuring that the earthing systems are adequately and independently earthed.
2) In certain cases, the generator will experience less voltage dips originating from the Distribution Network.
3) It could be a means of reducing the fault level infeed into the Distribution Network.

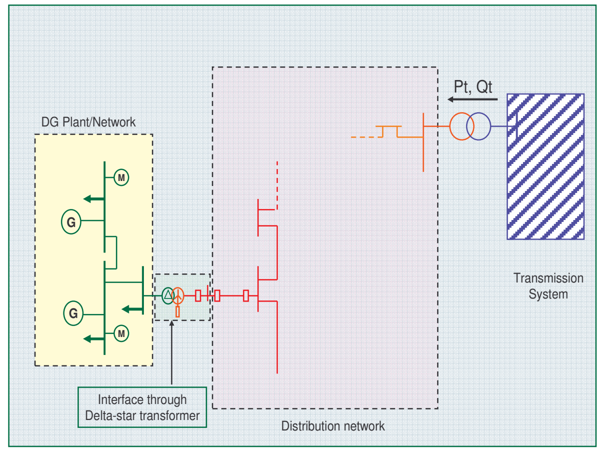

Figure 2: DG Plant/TNB Network Interface through delta-star transformer

Although the design and configuration of a new DG Plant is the responsibility of the DG Developer, there are basic requirements to be met for ensuring safe and secure operation of the integrated systems. These basic requirements of the DG Plants are:

1. The Generator star shall be earthed or grounded.
2. The choice of generator neutral grounding is up to the DG Developer. However, the followings should be noted:
    - normally DG units are designed to withstand maximum 3-phase fault current but not necessary unrestricted phase-to-ground fault current;
    - use resistor to limit earth-fault current to 300A irrespective of size is a common practice with step touch voltage within the criteria limits.
3. Two-or three winding transformer with star winding on the Distributor side.
4. The star side of the transformer which connects to the Distributor's network shall be grounded through an NER designed to limit earth fault current of 150A to flow from the generator side on a single-line to ground fault on the star side of the generator transformer (See Figure 3).

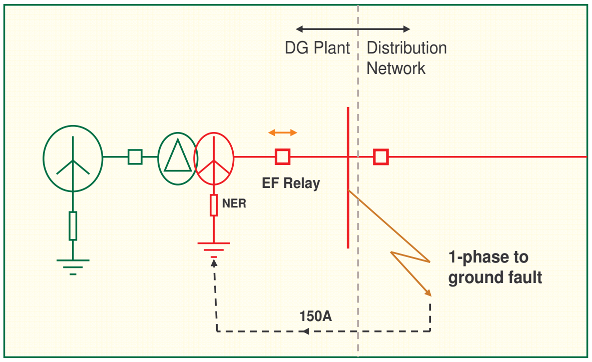

Figure 3: Earthing/grounding at the interface

5. An earth fault relay must be installed to detect earth faults on the Distributor's network fed from the Generator and to disconnect the DG network from TNB's network.
6. The designated connection point of DG Plant to TNB network must include a means of isolation.
7. DG unit control system must include synchronization facilities to enable the generator to be connected to the distribution network.
8. All necessary interlocks must be clearly described in the interface design.

Planning & Connection Process

The Guidebook provides a detailed description on the process to be connected that comprises several phases/stages: a) project planning; b) exchange of planning information; c) project design; d) project construction; e) project testing and commissioning; and f) project operation.

It also highlights the 2-level of assessments practiced [1] i.e. i) Preliminary System Study during stage b) and Power System Study at stage c). The main objectives of the preliminary system study are:

1) To determine network capability to accommodate the proposed DG; and
2) To establish cost estimate of the connection of the DG Plant to the network of the part of the circuit facilities that will come under the operational responsibility of the Distributor.

Once the project is confirmed to proceed and more information are derived at the design stage, the objectives of the Power System Study are:

1) To identify additional controls and protection and operating strategies for the DG plant when connected to the distribution network.
2) To be used by DG Developer to establish relevant specifications for DG plant and its interface with the distribution network.

DG Operation

With regards to DG operating in parallel with the Distribution Network, The Guidebook emphasizes 4 operating modes i.e. a) Constant MW output for whole day, b) MW output following load demand – load following, c) MW output depending fuel supply variations and d) zero MW output.

It also specifies the details for the establishment of 'Connection Operation Manual', preparation and review of 'Annual Operation Plan', specification of SCADA automation, etc., to ensure that operational safety and flexibility are not compromised..

CONCLUSIONS

In spite of the low level of DG penetration in Malaysia, the technical issues associated with DG connection need to be adequately, consistently and transparently managed.

The publication of the revised technical guidebook based on past experiences, industry inputs and experts opinions is timely as a means of providing clear and unambiguous technical guidelines, process and procedures. With this Guidebook as a reference and guidance, it is hope that learning and growth could take place among industry stakeholders to the extend that there would be "no significant technical barriers to DG access".

Meanwhile, these guidelines would be "put to test" and reviewed accordingly by industry stakeholders as TNB strives to find better cost-effective solutions based on its own or overall industry experience.

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