Power System Study for Renewable Energy Interconnection in Malaysia

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Abstract. The renewable energy (RE) sector has grown exponentially in Malaysia with the introduction of the Feed-In-Tariff (FIT) by the Ministry of Energy, Green Technology and Water. Photovoltaic, biogas, biomass and mini hydro are among the renewable energy sources which offer a lucrative tariff to incite developers in taking the green technology route. In order to receive the FIT, a developer is required by the utility company to perform a power system analysis which will determine the technical feasibility of an RE interconnection to the utility company’s existing grid system. There are a number of aspects which the analysis looks at, the most important being the load flow and fault levels in the network after the introduction of an RE source. The analysis is done by modelling the utility company’s existing network and simulating the network with the interconnection of an RE source. The results are then compared to the values before an interconnection is made as well as ensuring the voltage rise or the increase in fault levels do not violate any pre-existing regulations set by the utility company. This paper will delve into the mechanics of performing a load flow analysis and examining the results obtained.

1. Introduction
The renewable energy industry in Malaysia has seen a steady uprising in the past year largely due to the introduction of the Feed-In-Tariff incentive by the Ministry of Energy, Green Technology and Water. The FIT is an incentive handed out by the government to entice industry players to commit to long term renewable energy generation with a substantial profit gain for the industry. This incentive is within the government’s effort to promote renewable energy plants that will reduce the amount of generation supplied from conventional power plants which simultaneously reduces the amount of CO2 released into the atmosphere by the burning of fossil fuel.

With the introduction of the FIT, an overseeing entity was set up to implement and ensure the fairness and transparency of the system. The Sustainable Energy Development Authority (SEDA) is the regulatory body which has been tasked by the government to handle the renewable energy industry while operating at all times within the guidelines of the Renewable Energy Act.¹ There are a number of pre-requisites one must have to be awarded with the FIT and most notably in the list of the pre-requisites is the Power System Study (PSS). This paper will look into the technical aspect of the PSS to give readers a brief overview of the process involved in performing a PSS.

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2. Power System Study Overview

In this section we discuss the overall aspect of the PSS and the parameters observed when performing a PSS. The PSS is valid for a number of renewable energy sources such as Photovoltaic, Mini-Hydro, Biogas and Biomass. There are four main aspects to the PSS. They include:

- Load Flow Analysis
  - Power Flow
  - Voltage Regulation
  - Network Losses
- Short Circuit Analysis
- Dynamic Analysis (Photovoltaic Plants)

The PSS is conducted by using DigSilent Power Factory, a power systems analysis program tool developed by DIgSILENT GmbH, a Consulting and Software Company providing highly specialized services in the field of electrical power systems for transmission, distribution, generation and industrial plants. These analyses are performed based on the loading in PSS Adept, obtained from the utility company in Malaysia.

2.1 Load Flow Analysis

2.1.1 Power Flow analysis is performed to determine the direction of power flow in the distribution network with the interconnection between TNB and the proposed power plant. This would determine the adequacy of the distribution network to absorb the active power from the proposed PV plant. The load flow analysis is performed under steady state conditions. It is important to note the utility’s requirement that reverse power flow must not occur back to the transmission network.

2.1.2 Voltage regulation analysis is performed to determine if the steady state voltage levels at the busses are within the limits planned and declared by TNB at ±5% variation during normal operating conditions. If and when these voltages are above the limits declared by TNB, the interconnection of an RE source becomes impossible unless certain measures are taken to reduce the voltage levels to acceptable values. One such measure is to control the power factor of the generator to induce a drop in the voltage levels.

2.1.3 Network Losses analysis is performed to determine the effect on network losses with the connection of an RE plant. The losses which are taken into consideration for the PSS is the interconnection cable losses between the RE plant and TNB’s network as well as the transformer losses at the RE plant. The overall network losses is not discussed in the PSS. However, it has been shown that there is a reduction in losses for the overall network with the interconnection of an RE plant.

2.2 Short Circuit Analysis

Short circuit analysis is performed to indicate that all nodes are within the equipment short time rating as specified by TNB, hence complying TNB’s circuit breaker duty capability. Fault level data for the 132 kV buses at the source is obtained from TNB Transmission. These values are used in DigSilent to calculate the source impedance as well as the downstream distribution buses short circuit values. Based on the results of short circuit analysis, the operational safety of the network configuration for interconnection between the proposed power plant and TNB substation can be determined.

2.3 Dynamic Analysis

For PV plants, a dynamic analysis is important since the power generation is constantly varying due to the changing solar radiation throughout the day. The varying power generation injected into the utility network is bound to create voltage fluctuations at the interconnection point and other buses upstream on the grid. The objective of the dynamic analysis is to determine the level of voltage fluctuations. At
present, there is no guideline in TNB regulations, the Malaysian Distribution Code, or Malaysian Standards on the maximum percentage of voltage fluctuation allowed due to intermittent generation like solar PV, although the Malaysian Distribution Code allows voltage fluctuation of ± 3% for load switching. The following limits for intermittent generation are provided by some of the international codes:

| Standards               | Lower limit | Upper limit |
|-------------------------|-------------|-------------|
| IEEE 1547               | -8.3%       | +5.8%       |
| German Grid Code        | ±2% - Once in 3 minutes | ±5% - Generator disconnections |
| Spanish Grid Code       | -3 to 5%    | +3 to 5%    |

It appears that the maximum voltage fluctuation range that can be safely allowed is 6% (±3). Beyond that, there is a danger of utility and consumer equipment getting heated up. The dynamic analysis is carried out in DigSilent using the load data from PSS Adept and solar radiation data which is recorded using a pyrometer. The simulation is typically carried out for the period 7am to 7pm, with 3 minute interval readings of the solar radiation.

3. Example of Load Flow Analysis
In this section, an example of the results obtained from a load flow analysis will be shown. An arbitrary study is taken and the results are displayed below:

- **Voltage**
  Load flow studies are performed on the system to assess the impact of on the voltage at the sub-stations involved, with and without the RE plant.

| Table 2. Summary of Voltage Impact at TNB Substations |
|------------------------------------------------------|
| **At point of connection**                           |
| PE ABC                                               |
| **At PMU DEF (33kV)**                                |
| **Without RE**                                       |
| With 1MWₚₑPV                                        |
| Diff [%]                                             |
| Without RE                                          |
| With 1MWₚₑPV                                        |
| Diff [%]                                             |
| 11.028                                               |
| 11.104                                               |
| 0.7                                                  |
| 33.902                                               |
| 33.902                                               |
| 0.0                                                  |

Findings: Slight change of voltage at PE ABC. No significant steady-state voltage variation as a result of Solar PV system connection. Change in voltage is within ±5% limits.

- **Summary of Losses**
  Losses level is compared based on overall simulated network with and without the PV connection.
Table 3. Summary of Losses

| Losses                          | TROUGH LOAD Without interconnection | TROUGH LOAD With PV Plant (1 MW<sub:pk</sub>) |
|---------------------------------|-------------------------------------|---------------------------------------------|
| Losses in 1 km ABC 240mm² cable | P (kW) 0.05                        | Q (kVAR) -1.03                              |
| (11kV to PE)                    |                                     |                                             |
| Transformer Losses              | P (kW) -1.00                       | Q (kVAR) 23.88                              |

Findings: There is a slight increase in losses with introduction of Solar PV generation. However, the overall losses in the distribution network is reduced with the introduction of PV generation.

4. Conclusion
A power system study is done to determine the technical feasibility of an RE interconnection to the utility company’s existing grid system. As discussed, there are a number of aspects which the analysis looks at, the most important being the load flow and fault levels in the network after the introduction of an RE source. The PSS will thus determine if it is at all possible for an RE interconnection to occur. Once the PSS is done, the developer is required to obtain the report and use it to apply for the FIT therefor making the PSS a first step in developing an RE plant.

References
[1] Sustainable Energy Development Authority Malaysia (www.seda.gov.my)
[2] Grid Code, High and extra high voltage, EON Netz, German TSO