

Defining 'installed' and 'declared' capacity

This paper has been prepared to assist in providing appropriate information for the registration of systems under the Feed-In Tariffs.

1 Introduction

Registration of installations under the Feed-In Tariffs (FITs) requires two capacity figures to be specified:

- Total Installed Capacity (hereinafter 'TIC'), and
- Declared Net Capacity (hereinafter 'DNC').

Both expressions are also used for the Renewables Obligation (RO) and defined in legislation. The definitions coincide closely with the way fuel-burning generation plant is typically rated.

However, variable plant – whose performance is dependent on intermittent input energy such as sunlight, wind or water head and flow – is normally rated differently usually by stating performance at one (or more) given set(s) of instantaneous operating conditions. This is why the concept of Declared Net Capacity (as used for national and international government figures¹) was originally conceived. The new definitions used for the FITs and the RO differ from the statistical definition of DNC² and also industry practice for rating variable output equipment.

This paper is intended to derive a way of obtaining a capacity figure for such installations, which is in line with the statutory definitions.

2 Defined measures of capacity

The two capacity measures are both defined in the Statutory Instrument, by reference to the Standard Licence Conditions, as follows:

“Total Installed Capacity” means the maximum capacity at which an Eligible Installation could be operated for a sustained period without causing damage to it (assuming the Eligible Low-carbon Energy Source was available to it without interruption), a declaration of which is submitted as part of the processes of ROO-FIT Accreditation and MCS-certified Registration;

“Declared Net Capacity” means the maximum capacity at which the installation can be operated for a sustained period without causing damage to it (assuming the source of power used by it to generate electricity was available to it without interruption) less the amount of electricity that is consumed by the plant;

MCS certification standards for installations give details of how system performance should be specified for the purpose of defining annual output estimates, but not on how the above capacity measures are derived for individual installations.

1 Now called REStats, and in line with the International Energy Agency and EuroStats definitions. See online at <http://www.restats.org.uk/methodologies.htm>

2 It is obviously unfortunate that two branches of Government define differently the same technical term, but that is for others to resolve

Clearly the precise interpretation of these definitions will affect the figures given particularly for variable energy technologies such as hydro, solar, tidal³, wave³ and wind. In these cases the result will be affected in particular by the interpretation of:

- 'installation' (see section 3 below);
- 'capacity' (see section 4 below);
- 'sustained period' (see sections 5 below); and
- 'available without interruption' (also covered in sections 5 below)

Our proposed interpretation is detailed in the following sections.

3 Characteristics of an 'installation'

We would presume that, as capacity is related to each specific system and 'submitted as part of the processes of ROO-FIT Accreditation and MCS-certified Registration', this is specified individually for each installation and is thus specific to the location and configuration of the system.

Accordingly this needs to account for fundamental characteristics of the installed system, such as, for example, the orientation of a solar array or the hub height of a wind turbine.

It would not, however, make allowances for obstructions, near which the system has been installed. As further discussed in sections 4 below, it is assumed that these would reasonably be interpreted as 'interruption' to the energy source rather than characteristics of the system.

4 Variations between measures of 'capacity'

It would be reasonable to define the 'capacity' of an energy system as its output capability expressed (for the purpose of the Tariffs) in kilowatts.

The most obvious approach would be to measure this value at the point where the energy is metered and delivered to the user and the grid. However this would lead to exactly the same values for both 'total installed capacity' and 'declared net capacity' (except in unusual cases where there is a separate electricity input connection to provide the 'electricity that is consumed by the plant').

We have therefore assumed (by reference to the two statutory definitions given above) that the DNC is defined at the output meter, but that TIC is intended to add back internal electrical losses within the system, and is therefore defined at the point where the incoming energy source is converted to electricity.

The considerations in the following sections would therefore apply to the calculation of TIC. System losses, including the following, would be deducted to obtain DNC:

- Solar array mismatch losses
- Power consumed by pitch and yaw controls
- Power consumed by other feathering or other over-speed protection devices
- Power conditioning losses
- Voltage drops in lightning suppression and other protection devices
- Voltage drops in metering and other control circuitry

3 Not currently FIT-eligible technologies, but the principles will be the same if they are admitted at a later date

5 Sustained, uninterrupted operation of the installation

The interpretation of capacity for an installation defined as per section 3 above will depend on the characteristics of the specific technology. The relevant eligible options⁴ are considered individually below.

5.1 Biogas and other fuel-burning generation sources

The definitions used were conceived with these sources in mind, so interpretation is relatively straightforward. The equipment supplier typically rates the generator specifying its electrical output for a given input gas flow.

The TIC will therefore be the capacity of the generator rated at the maximum biogas flow rates expected to be sustained by the system.

The DNC will net off from the TIC any electrical losses within the system between the generator and the metered output connection.

5.2 Solar photovoltaic systems

In a PV system it is the solar cells, which convert the incoming (light) energy to DC electricity. The system usually also includes power conditioning equipment, and often an inverter which converts the DC power to output (usually AC) electricity. Some systems also incorporate a battery bank.

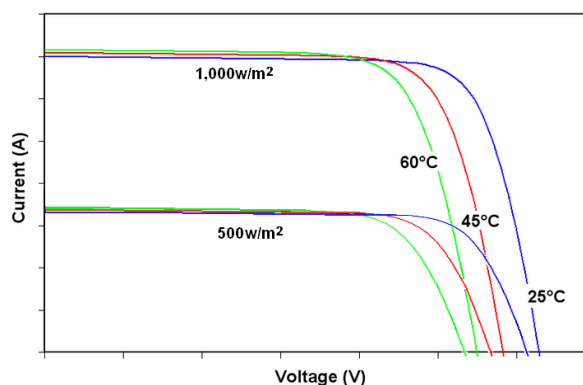
Primary energy conversion

Solar cells are mounted and interconnected in solar modules each rated in terms of their so-called 'peak power'. This is the instantaneous power delivered by the cell string under a defined set of conditions of irradiance, light spectrum and temperature. For uniformity of interpretation, these conditions have been defined in international standards at 1000w/m² at 25°C and AM1.5 spectrum⁵. These do not correspond to conditions applicable to the TIC definition because:

- irradiance levels in the UK are typically lower than 1000w/m²;
- at maximum output, normal cell operating temperature exceeds 25°C; and
- the AM1.5 spectrum is not appropriate for UK latitudes⁶.

Solar modules have a family of current-voltage performance characteristics depending on the surface irradiance, cell temperature and light spectrum. Each curve has a 'peak power point' where the product of current and voltage is maximum.

The actual operating voltage will be dependent on the circuit to which the array is connected (such circuitry normally being designed to keep this close to the peak power point).



⁴ Only FIT-eligible electrical technologies are considered in this paper – heat technologies can be added later if similar considerations become relevant.

⁵ Used in the international standards IEC61215 (crystalline) and IEC61646 (thin film cells)

⁶ Indeed a test site in Malta used to be used by UK experts to approximate these standards

Power curves against irradiance and temperature can then be constructed from these characteristics, and are typically fairly linear in the range of irradiance levels between about 100w/m² and 2,000w/m².

TIC definition

Based on the principles for defining the respective capacity measures in section 3 above, the TIC would be based on the output capability of the solar array given uninterrupted exposure to sunlight over a sustained period at its installed location. Suitable data on which this figure can be based is produced by the European Commission's Joint Research Centre at Ispra, which maintains a resource called the Photovoltaic Geographical Information System (PVGIS)⁷.

PVGIS is based on extensive solar energy data throughout Europe. It has facilities to derive for any location and solar array angle three irradiance measures:

- Global 'clear sky' irradiance
- Global 'real sky' irradiance
- Diffuse 'real sky' irradiance

We propose to use the best month's clear sky irradiance as the basis for the TIC calculation. This is the highest of the three figures, and that which best matches the 'without interruption' requirement of the definition.

We will use actual tilt angle and azimuth offset figures for installations constrained by the surface on which they are mounted (e.g. roofs). In the case of stand-alone and ground-mounted PV systems we will use the optimum tilt angle (also given by the PVGIS resource), and assume the array is oriented towards true South.

The TIC will then be calculated as the power output of the solar array at the average irradiance derived in this way.

DNC definition

The net output of a PV system, after conversion of light energy in each solar module, will be affected by configuration factors, such as 'mismatch' losses from the series and parallel interconnection of the modules, cable losses, voltage drops in metering and protection devices and the efficiency of the inverter and any other power conditioning equipment.

As described in section 4 above, it is proposed that these factors are deducted from the TIC to derive the DNC.

5.3 Wind energy systems

In a wind power system the turbine blades convert the energy from the air-flow into circular motion. This is typically converted to DC or AC electricity by a generator coupled to the blades (though other configurations may be used). In most systems the electricity is then conditioned to feed in to, or operate in parallel with, the grid.

Primary energy conversion

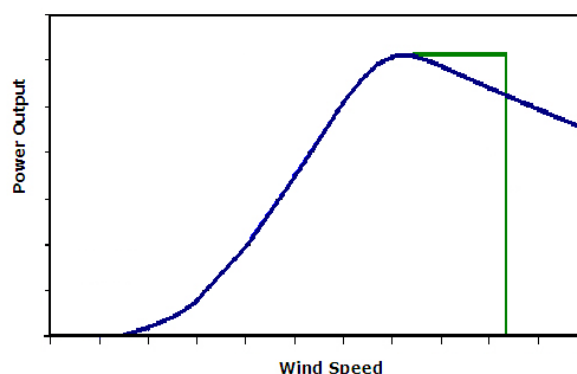
In this case the combination of the blades, the drive train and the generator should be considered to be the primary conversion mechanism. Turbines are typically rated for one or more specified wind-speeds based on their power curve.

⁷ See: <http://re.jrc.ec.europa.eu/pvgis/>

These ratings do not match the TIC definition, unless the wind-speed at which capacity is rated matches the wind regime applicable to the installation.

Wind turbines are characterised with power curves of power output against wind-speed⁸. This is not linear (in fact power theoretically varies with the cube of the wind-speed), so the output cannot simply be integrated over a range of wind-speed measurements.

The form of the curve at high wind-speeds depends on the over-speed protection of the turbine.



TIC definition

There are no known data sources which indicate what wind-speed might be experienced for a sustained period for installations at sites around the UK. However there is a government database of average wind-speeds called the Numerical Objective Analysis of Boundary Layer model (NOABL)⁹.

NOABL is calculated to show the wind-speed at unobstructed sites so is appropriate for assessments of availability of wind energy without interruption. It derives figures at three standard elevations of 10m, 25m and 40m.

Empirical measurements suggest that the maximum wind-speed sustained at any site is typically about twice the calculated NOABL average for that location, and it should be possible to refine this figure as further data becomes available. We therefore propose to rate the TIC of a wind installation, using the certified power curve for the device, as the rated power output at a wind-speed of $F_w \times V_w$, where:

- F_w is a fixed constant, initially 2, and
- V_w is the average wind-speed for the installation, derived from
- actual on-site measurements at the designated hub height taken over a period of no less than one year, if available, failing which;
- NOABL data for the designated hub height (or, if not at one of the NOABL standard elevations, extrapolated linearly from the two nearest values).

DNC definition

The net output of a wind energy system, after conversion of the wind energy in the turbine, will be affected by various factors, such as power used in pitch and yaw controls, cable losses, voltage drops in metering and protection devices and the efficiency of any inverters, transformers or other power conditioning equipment.

As described in section 4 above, it is proposed that these factors are deducted from the TIC to derive the DNC.

⁸ International standard IEC61400 details how these should be derived.

⁹ First published by the former DTI and now accessible through the DECC website at: http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/explained/wind/windsp_databas/windsp_databas.aspx

5.4 Hydro-power systems

Most hydro-power systems convert energy from a water flow into circular motion of a turbine, screw or water wheel. This is typically converted to DC or AC electricity by a generator coupled to the turbine. The electricity is then normally conditioned to feed in to, or operate in parallel with, the grid.

Primary energy conversion

There are many different turbine technologies to suit a wide range of head and flow rate combinations; both reaction turbines (including Francis, Kaplan, Tyson, Archimedean screw and water wheels) and impulse turbines (including Pelton wheels, Turgo and Crossflow). Each can be rated in terms of a family of power curves against the head and flow rate.

Capacity definition

We have not as yet evolved a satisfactory way of defining what head and flow rates would be appropriate to use for uninterrupted input over a sustained period; and the MCS has yet to publish hydro-power standards. Therefore we propose to consider it at a later date and update this paper in due course.

Document Reference:	F2RCAP1d
Issue number and status:	1-0 Draft
See document management system for approval details & dates	