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**Estimation method of generating
electric energy by PV power system**

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Foreword

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Estimation method of generating electric energy by PV power system

1 Scope This Japanese Industrial Standard specifies estimation method of annual electric energy by photovoltaic power generating system (hereafter referred to “PV system”) corresponding to the following:

- a) The objects are grid-connected PV system and stand-alone PV system with an output not less than 1 kW and an open-circuit photovoltaic array voltage not exceeding 750 V. However, directly connected water pump system and hybrid system are excluded.
- b) For photovoltaic array, storage battery and power conditioner which consist the system, the following specifications apply:
 - 1) The photovoltaic array shall consist of silicon cell modules of the same type crystal system (single crystal and polycrystal), have a single plain and be fixed type. The array circuit shall be formed by connecting strings in parallel.
 - 2) The battery used for this system shall be a lead storage battery.
 - 3) Variable voltage and/or variable frequency power conditioner is excluded.

Remarks : The following Annexes are shown for information.

Annex 1 (informative) Calculation of monthly averaged daily total irradiation

Annex 2 (informative) Classification of design parameters

Annex 3 (informative) Estimation method of temperature rise of photovoltaic array for roof

2 Normative references The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS C 8702-1 *Small-sized valve regulated lead-acid batteries—Part 1: General requirements, functional characteristics—Methods of test*

JIS C 8702-2 *Small-sized valve regulated lead-acid batteries—Part 2: Dimensions, terminals and marking*

JIS C 8702-3 *Small-sized valve regulated lead-acid batteries—Part 3: Safety recommendations for use in electric appliances*

JIS C 8704-1 *Stationary lead-acid batteries—General requirements and methods of test—Part 1: Vented types*

JIS C 8704-2 *Stationary lead-acid batteries—General requirements and methods tests—Part 2: Valve regulated types*

JIS C 8918 *Crystalline solar PV module*

JIS C 8951 *General rules for photovoltaic array*

JIS C 8952 *Indication of photovoltaic array performance*

JIS C 8960 *Glossary of terms for photovoltaic power generation*

JIS C 8961 *Measuring procedure of power conditioner efficiency for photovoltaic systems*

JIS C 8980 *Power conditioner for small photovoltaic power generating system*

3 Definitions For the purpose of this Standard, in addition to the definitions of **JIS C 8960**, the following principal definition apply:

- a) **array circuit correction factor** a factor to correct the resistance loss caused by resistance of wiring of photovoltaic array and the loss due to blocking device
- b) **array load matching correction factor** a factor which corrects the reduction of electric energy due to such phenomenon that the actual operating voltage shifts from the maximum output operating voltage of the photovoltaic array output power when a load is connected to the PV system
- c) **battery charge-discharge efficiency** the ratio of discharged ampere-hour to the charged ampere-hour of a storage battery
- d) **fundamental design factor** the factor which is the quotient of total design factor by cell temperature factor
That is $(\text{fundamental design factor}) = (\text{total design factor}) / (\text{cell temperature factor})$.
- e) **directly connected water pump system** a system which pumps up water by driving a pump(s) using the energy obtained by the photovoltaic power generation as the power source
- f) **standard module output** the output at the maximum output point of a module under standard test conditions
- g) **open rear type** such a type (of module) that the rear face of module is directly opened to the atmosphere under installed state
- h) **closed rear type** such a type (of module) that the rear face of module is closed so that there is no circulation of air under installed state
- i) **frame mount type** a type of module which is mounted on a support structure
- j) **roof mount type** a type of module which is mounted on a roof as stand-off state
- k) **building integrated type** a type of module which is integrated with such building materials as roof material, facade material, etc.
- l) **roof integrated type** a type of module which is integrated with roof material from among building integrated type
- m) **solar radiation fallow up load** a load which is almost proportional to solar radiation
- n) **weighted average module temperature** averaged module temperature weighted by solar irradiance

- o) **weighted average module temperature rise** the difference between the average module temperature weighted by solar irradiance and the air temperature

This is the rough estimate of array temperature rise as the average value.

4 Fundamental structure of applicable system The fundamental structure of system is shown in figures 1 to 3. Each component equipment shall be that given in table 1 or that at least equivalent in performance.

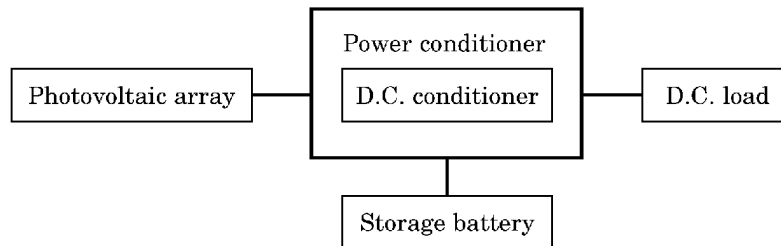


Figure 1 Stand-alone PV system with d.c. load only

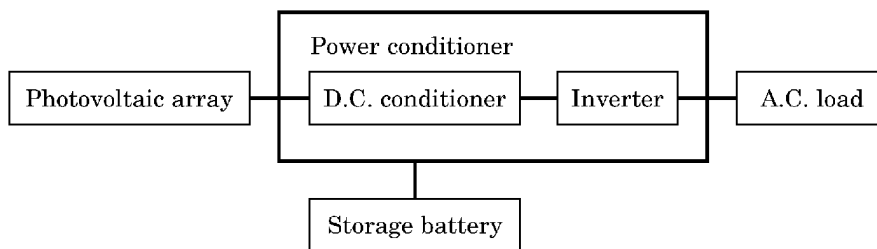
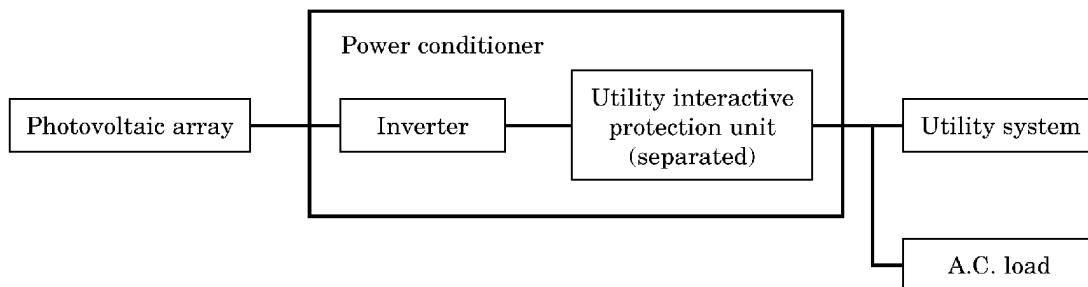
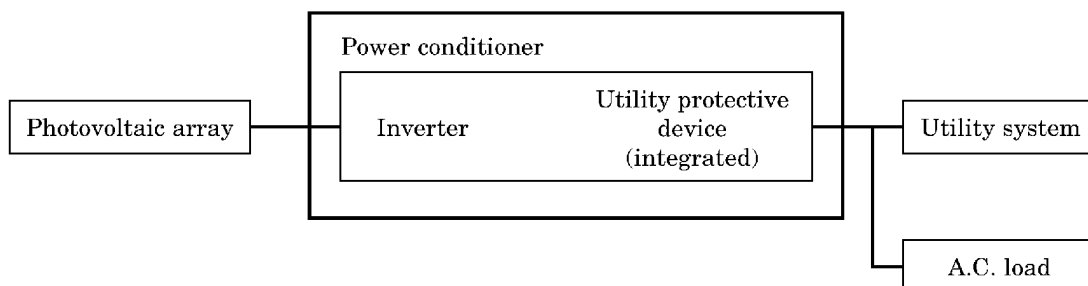


Figure 2 Stand-alone PV system with a.c. load only



a) Separate utility protection unit type



b) Integrated utility protection unit type

Figure 3 Utility connected PV system without storage battery

Table 1 Component equipment

Component equipment	Applicable standard
Photovoltaic array (module)	JIS C 8918 JIS C 8951 JIS C 8952
Power conditioner	JIS C 8980
Accumulator (lead-acid battery)	JIS C 8702-1 JIS C 8702-2 JIS C 8702-3 JIS C 8704-1 JIS C 8704-2

5 Estimation method of annual electric energy generated by system

5.1 Estimation procedure of annual electric energy generated by system The method to estimate annual electric energy generated by a system shall be as follows:

- Confirmation of specifications of the PV system
- Confirmation of installation place of the PV system
- Confirmation of STC photovoltaic array maximum power P_{AS}
- Calculation of fundamental design factor K' (cell temperature factor is excluded from total design factor)
- Selection of monthly averaged daily total irradiation H_S
- Calculation of monthly integrated total irradiation H_{Am}
- Calculation of cell temperature factor K_{PT}
- Calculation of monthly total design factor K
- Estimation of monthly electric energy generated E_{Pm} by the system
- Estimation of annual electric energy generated E_{Py} by the system

5.2 Confirmation of specification of PV system The specifications stated below of the aimed PV system shall be confirmed and entered in the PV system specification sheet (table 2).

- Kind of photovoltaic cell
- Standard module output
- Number of modules
- Style of module installation (confirmation of open rear type or closed rear type)
- Maximum power temperature coefficient (use the value in table 5 if not available)
- Array azimuth

- g) Array tilt angle
- h) System style [identification of utility connected system or stand-alone system (d.c. load/a.c. load)]
- i) Kind of load (solar radiation following load or not)
- j) Existence or non-existence of storage battery

5.3 Confirmation of installation place of PV system The installation place of the aimed PV system shall be confirmed, then the name of place, the longitude and the latitude shall be entered in the PV system specification sheet (table 2).

5.4 Confirmation of STC photovoltaic array maximum power P_{AS} The STC photovoltaic array maximum power (in accordance with **JIS C 8952**) shall be confirmed.

If this is not described, this parameter shall be calculated in accordance with formula (1) as the tentative value and entered in the PV system specification sheet (table 2).

$$P_{AS} = P_{MS} \times n \quad \dots\dots\dots (1)$$

where, P_{MS} : output per one photovoltaic module under the standard test conditions described in the specification or technical data of the manufacturer (kW)

n : quantity of photovoltaic module (number of modules)

5.5 Calculation of fundamental design factor K' The fundamental design factor shall be obtained in such a manner that each correction factor is made clear in accordance with the procedures given below for each basic constitution of the system, then each fundamental design factor so obtained is entered in the fundamental design factor calculation sheet (table 3).

The general expression of correction factor shall be as stated in Annex 2.

- a) **Annual irradiation deviation factor K_{HD}** For annual irradiation deviation factor, the value in table 5 shall be used.
- b) **Efficiency deviation factor K_{PD}** For efficiency deviation factor, the value from the module manufacturer shall be adopted if available. In other cases, the value in table 5 shall be used.
- c) **Array circuit correction factor K_{PA}** For array circuit correction factor, the value in table 5 shall be used.
- d) **Array load matching correction factor K_{PM}** For array load matching correction factor, the value in table 5 corresponding the kind of system shall be used.
- e) **Battery contribution ratio γ_{BA}** For battery contribution ratio, the value in table 5 shall be used.
- f) **Battery charge-discharge efficiency η_{BA}** For battery charge-discharge efficiency, the value in table 5 shall be used.

g) **Inverter effective energy efficiency η_{INO}** Inverter effective energy efficiency is a factor used in the case of utility connected type and stand-alone type (a.c. load), and the value shall be determined as stated in the following, respectively:

- 1) **For utility connected type** When the effective energy efficiency (in accordance with JIS C 8961) is shown by the inverter manufacturer, the value shall be used. In other cases, the value in table 5 shall be used.
- 2) **For stand-alone type** The annually averaged load factor (annually averaged electric energy of load per hour/rated input power of inverter) is calculated, and the efficiency is obtained from the efficiency curve obtained from the manufacturer.

h) **DC/DC converter effective energy efficiency η_{DDO}** When the efficiency at the ratings is available from the manufacturer, the value is used for the DC/DC converter effective energy efficiency. In other cases the value in table 5 is used.

i) **Calculation of fundamental design factor K'** The fundamental design factors shall be obtained from the formulae (2) to (4) for utility connected type, stand-alone type (d.c. load) and stand-alone type (a.c. load), respectively.

- 1) **For PV system of utility connected type having no storage battery**

$$K' = K_{HD} \times K_{PD} \times K_{PM} \times K_{PA} \times \eta_{INO} \dots\dots\dots (2)$$

- 2) **For stand-alone type (d.c. load)**

$$K' = K_{HD} \times K_{PD} \times K_{PM} \times K_{PA} \times (1 - \gamma_{BA} + \gamma_{BA} \times \eta_{BA}) \times \eta_{DDO} \dots\dots (3)$$

- 3) **For stand-alone type (a.c. load)**

$$K' = K_{HD} \times K_{PD} \times K_{PM} \times K_{PA} \times (1 - \gamma_{BA} + \gamma_{BA} \times \eta_{BA}) \times \eta_{INO} \dots\dots (4)$$

5.6 Selection of monthly averaged daily total irradiation H_S The name of the closest place to the installation point of the photovoltaic power system is selected in accordance with the instruction manual from the attached CD-ROM, then the monthly average daily total irradiation at the array azimuth and tilt angle of the closest point so selected is read from the file. The values so read are entered monthly in the calculation sheet for estimated electric energy by PV system (table 4).

5.7 Calculation of monthly total solar irradiation H_{Am} The monthly total solar irradiation shall be obtained by multiplying monthly averaged daily total irradiation determined in 5.6 by the number of days in the month using the formula (5). The obtained value is entered in the calculation sheet for estimated electric energy by PV system (figure 4).

$$H_{Am} = d \times H_S \dots\dots\dots (5)$$

where, H_S : monthly averaged daily total irradiation (kWh · m⁻² · d⁻¹)

d : number of days in the month

5.8 Calculation of cell temperature coefficient K_{PT} The cell temperature coefficient shall be calculated as follows:

- a) **Handling of maximum power temperature coefficient** If the maximum power temperature coefficient is not available from the manufacturer or the like, it shall be selected according to the kind of module by using table 5.

When the maximum power temperature coefficient is available, but the unit is expressed in $W \cdot ^\circ C^{-1}$, the unit shall be converted to $\% \cdot ^\circ C^{-1}$ by using the formula (6).

$$\alpha_{P_{max}} = \alpha_{P_{max0}} / P_{M_{MAX}} \times 100 \quad \text{..... (6)}$$

where, $\alpha_{P_{max}}$: maximum power temperature coefficient ($\% \cdot ^\circ C^{-1}$)

$P_{M_{MAX}}$: STC photovoltaic module maximum power (W)

$\alpha_{P_{max0}}$: maximum power temperature coefficient obtained ($W \cdot ^\circ C^{-1}$)

- b) **Calculation of weighted average module temperature** The weighted average module temperature shall be calculated by the formula (7), from the monthly averaged air temperature at the point selected in 5.6 and the weighted average module temperature rise given in table 5 appropriate to the installation style.

Details of estimation method of temperature rise of photovoltaic array for roof are given in Annex 3.

$$T_{CR} = T_{AV} + \Delta T \quad \text{..... (7)}$$

where, T_{CR} : weighted average module temperature ($^\circ C$)

T_{AV} : monthly average air temperature (use the value obtained from the attached CD-ROM)

ΔT : weighted average module temperature rise

- c) **Calculation of cell temperature factor** The cell temperature factor shall be calculated by using the formula (8) for each month, then entered in the calculation sheet for estimated electric energy by PV system (table 4).

$$K_{PT} = 1 + \alpha_{P_{max}}(T_{CR} - 25)/100 \quad \text{..... (8)}$$

where, $\alpha_{P_{max}}$: maximum power temperature coefficient ($\% \cdot ^\circ C^{-1}$)

5.9 Calculation of monthly total design factor K The monthly total design factor shall be calculated by using the formula (9), then entered in the calculation sheet for estimated electric energy by PV system (table 4).

$$K = K' \times K_{PT} \quad \text{..... (9)}$$

5.10 Estimation of monthly electric energy E_{Pm} generated by system The monthly electric energy generated by the system shall be calculated by formula (10), then entered in the calculation sheet for estimated electric energy by PV system (table 4).

$$E_{Pm} = K \times P_{AS} \times H_{Am} / G_S \quad \text{..... (10)}$$

where, E_{pm} : monthly electric energy of photovoltaic system
($\text{kWh} \cdot \text{month}^{-1}$)

G_{s} : irradiance in standard test conditions ($\text{kW} \cdot \text{m}^{-2}$)

5.11 Estimation of annual electric energy E_{py} generated by system The estimation of annual electric energy generated by the system shall be obtained by adding the individual monthly electric energy generated by the system obtained in 5.10, then entered in the calculation sheet for estimated electric energy by PV system (table 4).

Table 2 PV system specification sheet

Name of system			
	Item	System specification	Description
System specification	Kind of photovoltaic cell		Crystal system
	STC photovoltaic module maximum power P_{MS} (kW)		
	Number of photovoltaic modules n		
	Installation style of photovoltaic module		Rear open/rear closed
	Maximum power temperature coefficient		When available
	Array azimuth		
	Array tilt angle		
	System style		Utility connected/stand-alone (d.c. load/a.c. load)
	Kind of load		Solar radiation following load or not
	Existence or non-existence of storage battery		
Place of installation	Name of place		
	Latitude		
	Longitude		
STC photovoltaic array maximum power P_{AS} (kW)			$P_{\text{AS}} = P_{\text{MS}} \times n$