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Tracing of shading effect on underachieving SPV cell of an SPV grid using wireless sensor network

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ABSTRACT

The environmental and economic merits of converting solar energy into electricity via photovoltaic cells have led to its enormous growth in this sector. Besides material and design parameters, there are many other factors which locally affect Photovoltaic cell like partial shading, humidity, dust, bird droppings, air velocity etc. However, the effect due to a single solar photo voltaic cell being connected to a serial or parallel network (to form a grid) has never been deliberated extensively. In this paper a system design that will detect the underperforming panel in the entire grid is proposed and validated. All the Photo voltaic panels in a grid are connected with current sensors, which are connected to microcontrollers and these microcontrollers are locally connected with the wireless sensor network. With the help of wireless sensor network, grid monitoring for individual panel has been achieved for the first time with proposed system. The grid and control room is also connected wirelessly which enables the engineer monitoring the grid to meticulously locate the individual solar photovoltaic cell which is underachieving and solve the issue pertaining the same. The proposed system design has been validated with the help of data obtained with Centre for Wind Energy Technology (CWET), Govt. of India.".

1. Introduction

Rapid fossil fuel consumption and the green house effect have prompted the world to devote considerable resources for the research and development [29] [40]; of Solar Photo Voltaic (SPV) generation systems as solar energy is free, inconsumable and clean source of energy. The Solar energy received by the Earth is 15000 times more than the World's commercial energy consumption [18]. Developing countries like India is getting 5000 trillion kWh per year energy incident over its land area, with most parts of the country receiving 4–7 kWh per m^2 per day [32]. In most part of India, clear sunny day is experienced for 250–300 days a year [33] and the annual radiation varies with 1600–2200 kWh/m^2 [33].

For remote electrical power supply, stand-alone photovoltaic systems are developed [7,9]. Evolution of SPV array is leading to the design and installation of large sized PV plants. The structure of the SPV plant is governed by suitable parallel and series connections of the SPV cells [10,17], in this way it forms a grid connected photovoltaic systems [24].

The panel monitoring and control is the most important part of such systems. Lot of research is going on improving the efficiency of SPV's and large amount of money is invested by various governments to achieve so [39].

For any SPV, output characteristic depends on the environmental conditions. The output power is function of the temperature and the irradiance values of the site where panel is placed. This power varies as a result of any temperature and/or shining variations. However, performance analysis of this scheme in real conditions is generally a difficult task because several factors like ground clearance of SPV panels, soil (sandy, dusty, metallic rich etc.) condition of the surrounding area/soil particle size etc. are acting on it.

If any of the panel in the grid is not working then the entire grid's performance gets degraded and it is very difficult to locate

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Table 1
Summary of selected reported dust effects on solar photovoltaic (SPV) device performances for the period of 1942 to the present.

Reference	Location	Type of solar device	Period of study	Key findings	Comments and conditions
Hottel and Woertz [20]	Boston, MA, USA	Solar–thermal collectors	3 months	Maximum degradation during the test period was 4.7%	A correction factor of 0.99 (for a 45″ tilt angle)
Dietz [11]	NY, USA	Glass samples	3 months	At tilt angles between 0″ and 50″, the reduction in solar radiation due to dirt was 5%	
Sayigh [43]	Saudi Arabia	Solar collectors	25 days	Heat-collection reduction of 30% after 3 days without wiping	
Anagnostou and Forrestieri [6]	Cleveland, OH, USA	PV modules	1 year -	Degradation is site dependent.- Washing does not eliminate all degradation.- Permanent loss in maximum power reaches a steady value after several hundred days	Local condition is most damaging
Murphy and Forman [35]; **Forman** [15]	Lexington, MA, USA	PV module (glass)	18 months	Measurement of soil accumulation and model Cleaning using gloss meter	
Nimmo, Saed [36]	Saudi Arabia	Solar collectors& PV modules (glass)	6 months	26% and 40% reduction of efficiency from solar collector and PV panels, respectively	Dry conditions
Wakim [47]	Kuwait	PV modules (glass)	6 days	17% reduction in efficiency of module	
El-Shobokshy et al. [13] ;Zakzouk [49]	Saudi Arabia	CPV	1 month	Open-circuit voltage did not change, and short-circuit current and cell efficiency showed a large change with dust deposition	Concentrating PV study; effect on dust accumulation on cell temperature investigated; Modeling of series resistance effects
Bajpai and Gupta [8]	Nigeria	Silicon solar cell	4 months	Poor efficiency due to scattering of incoming radiation by dust particles	
Ryan et al. [41]	Oregon, USA	Solar module array (glass)	6 years	Unwashed solar cell array has degraded at a rate about 1.4% per year	Fluctuations in degradation (rates) do exist and long-term testing of degradation is needed
Said [42]	Saudi Arabia	Solar collectors& PV modules (glass)	1 year	7% reduction per month for PV panels and 2.8% to 7% for solar collectors	
Pande [37]	India	PV module (glass)	1 year	Reduction in current value due to dust was up to 30%	
Alamoud [4]	Riyadh, Saudi Arabia	PV module (glass)	1 year	Efficiency decreased by 5.73%–19.8% depending on the type of the module when exposed to outside environment	Compared module specifications to manufacturer's claims (differences). Hot, arid conditions
Adanu [2]	Ghana	PV system (glass)	4 years	Effect of dust particles in atmosphere generally reduces the solar irradiance and the energy output from the PV array	Time of day data reported. Cleaning by wiping of module surface
Kattakayam et al. [25]	India	PV module (glass)	Laboratory work	The loss of power due to accumulation of dust and the increase in temperature of the panel can be significant	Careful analysis of IV characteristic from operating PV field. Provides information on instrumentation for monitoring
Goossens, Van Kerschaever [16]	Israel	PV modules (glass)	Laboratory work	Fine dust deposition on the cell has significant effect on power output. Considered effects of due to air borne dust concentration and wind velocity. Reported losses in solar intensity on cells, open-circuit voltage, fill factor, short-circuit current and power as function of accumulation time. Power losses greater than 95%	Reported I–V characteristics as a function of the dust density
Hassan et al. [3]	Saudi Arabia	PV modules (glass)	6 months	33.5% and 65.8% reductions in efficiency after 1 month and 6 months.	