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Real-time monitoring and operation of power generation in a solar power plant with three phase central inverter topology

Üç fazlı merkezi invertör topolojisine sahip güneş enerjisi santralinde güç üretiminin gerçek zamanlı izlenmesi ve işletimi

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Abstract

In this article, real-time monitoring, control and operation of the power generation of Şenyurt (Erzurum/Turkey) Solar Power Plant (SPP) with a three-phase central inverter topology is discussed. In the study, firstly, the power generation model of Şenyurt SPP with direct grid feed and central inverter topology was examined. Secondly, the data obtained by means of solar radiation sensor, Photovoltaic (PV) panel temperature sensor, outdoor temperature sensor and wind speed sensor, which are vital for monitoring and controlling the power generation of SPP, were evaluated. Real-time data obtained from these sensors were obtained with the help of a remote monitoring interface compatible with the Central Control and Data Acquisition (SCADA) system in the SPP. With the data of the sensors, the graphs obtained regarding the change of one-day active power generation of the SPP are interpreted. Thus, the operational inspection of the SPP for uninterrupted active power generation was carried out. Finally, practical field applications such as cleaning the snow accumulated on the PV panel surface, detection of hot zone faults in PV panels, measurement of current-voltage (I-V) characteristics of PV panel arrays, which are necessary for efficient power generation in the solar power plant, are also included.

Keywords: Central inverter topology, Three phase inverter, Power monitoring and control, Solar power plant.

Özet

Bu makalede, üç fazlı merkezi inverter topolojisine sahip Şenyurt (Erzurum/Türkiye) Güneş Enerjisi Santrali (GES) güç üretiminin gerçek zamanlı olarak izlenmesi denetimi ve işletimi ele alınmıştır. Çalışmada ilk olarak doğrudan şebeke beslemeli ve merkezi inverter topolojisine sahip Şenyurt GES'in güç üretim modeli incelenmiştir. İkinci olarak, GES'in güç üretiminin izlenmesi ve denetimi için oldukça hayati öneme sahip güneş ışınımı sensörü, Fotovoltaik (FV) panel sıcaklık sensörü, dış ortam sıcaklık sensörü ve rüzgar hızı sensöründen elde edilen veriler değerlendirilmiştir. Bu sensörlerden elde edilen gerçek zamanlı veriler GES'de bulunan Merkezi Denetim ve Veri Toplama (MD&VT) sistemi ile uyumlu olan uzaktan izleme arayüzü yardımıyla elde edilmiştir. Sensörlere ait verilerle GES'in bir günlük aktif güç üretiminin değişimine ait elde edilen grafikler yorumlanmıştır. Böylece GES'in kesintisiz aktif güç üretimine dair işletime denetimi gerçekleştirilmiştir. Son olarak GES'de verimli bir şekilde güç üretiminin gerçekleştirilebilmesi için gerekli olan FV panel yüzeyinde biriken karların temizliği, FV panellerde oluşan sıcak bölge arızalarının tespiti, FV panel dizilerine ait akım-gerilim (I-V) karakteristiklerinin ölçümleri gibi pratik saha uygulamalarına da yer verilmiştir.

Anahtar kelimeler: Merkezi inverter topolojisi, Üç fazlı inverter, Güç izleme ve denetim, Güneş enerji santrali.

1 Introduction

The rapid increase of the world population, the economic enrichment of developing countries, the active use of artificial intelligence-based devices in every field increase the demand for energy day by day. In addition, energy is an indispensable requirement in many areas such as private residences, industrial manufacturing, tourism sector, health care and agricultural production areas [1]. Despite this, the Covid-19 pandemic, which started in late 2019 and is still ongoing, has brought short-term uncertainties about the future of energy. In addition, this global epidemic has brought serious economic consequences in almost all countries, especially in underdeveloped and developing countries. According to the updated assessments of the International Energy Agency (IEA) regarding the immediate effects of the epidemic on the energy system, they reported that they expect a 5% decrease in global energy demand, 7% in energy-related CO2 emissions and 18% in energy investment in 2020. They expect oil consumption to decrease by 8% and coal use by 7% in 2020 [2]. The biggest reasons for the small contraction in energy demand are the curfew restrictions of the countries in order to prevent the spread of the pandemic disease, the gradual working order of the production industry and the restrictions in almost all social life. Nevertheless, renewable electricity generation is the only major energy source that continues to grow in 2020, and this resilience sets the course for the next decade and beyond. Unfortunately, not only is the supply of oil, coal and natural

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gas limited, there are also significant pollution and environmental concerns associated with the use of traditional energy sources and alternatives. For this reason, the Paris Agreement, which was realized with the participation of 195 countries in December 2015, it was aimed to limit the pre-industrial temperature increase to 1.5 °C by keeping the average temperature increase of the world well below 2 °C [3]. The only way to fix the global temperature increase to 2 degrees or less is to prefer alternative renewable energy sources with low carbon emission, which do not emit greenhouse gases [4].

Among the renewable energy sources, solar Photovoltaic (PV) systems show an enormous spread and development as the favorite of electricity supply worldwide. Thanks to the innovations in photovoltaic technology, PV cells have managed to go beyond laboratory prototypes and go into commercial production as PV modules [5]. Especially in the last decade, the cost of producing solar panels has dropped significantly. This visible decline in the cost of solar panels has made them the cheapest type of electricity. Thus, it has reached a level where it can compete with other energy sources in electricity generation in residential, commercial applications and public service-scale projects. Since 2014, the global weighted average cost of electricity of solar photovoltaics (PV) has also fallen into the fossil-fuel cost range [6]. It is predicted that solar PV systems will grow an average of 13% per year between 2020 and 2030 and will meet almost one-third of the electricity demand during this period [2]. In 2020, the total capacity of solar photovoltaic (PV) installations worldwide reached 707,494 MW [7].

Besides all these positive predictions about energy with solar PV systems, the optimum performance of PV energy systems is affected by external factors related to the light intensity of the sun, the power conversion structure and the other internal components of the PV system, geographical location and environmental factors. One of the most important components of solar PV systems is inverters that convert the generated DC power into AC power, which is the grid voltage. An important issue in inverter structures used in grid-connected PV systems is to achieve high output power efficiency for different configurations at minimum cost. Moreover, real-time power monitoring and periodic control of the power plant is an important factor affecting the efficient power conversion of the SPP.

The purpose of this article is to provide a better understanding of the operation of a solar power plant with a three-phase central inverter structure. In addition, this study includes practical information about the operational maintenance and monitoring of a solar power plant with a three-phase central inverter structure, which is necessary for efficient energy conversion. This article is organized as follows. In section II, inverter topologies used in SPPs are discussed. Section III includes the structure, real-time monitoring, operation and maintenance procedures of a solar power plant with a central inverter structure. The last section addresses the discussion and conclusion part of this work.

2 Material and method

2.1 Inverter topologies of solar power plant

Solar PV modules used in SPPs generate DC power. However, to ensure that the DC power generated by the PV arrays flows into the AC grid, inverter systems that convert DC power to AC power must be used. In the last 10 years, the PV industry has grown rapidly in parallel with the developments in semiconductor and power electronics technologies. In particular, power electronics technology has played an important role in the development of new PV inverter topologies. Basically, two types of inverter structures are used in photovoltaic power conversions. These are power converters that use batteries directly independent of the grid and power converters that interact with the grid. Power inverters interacting with the electricity grid can be designed in accordance with central, string, module and multi-string structures. Figure 1 shows the different inverter topologies used in grid-connected solar power plants [8]. Each configuration consists of a combination of serial or/and parallel PV modules [9].

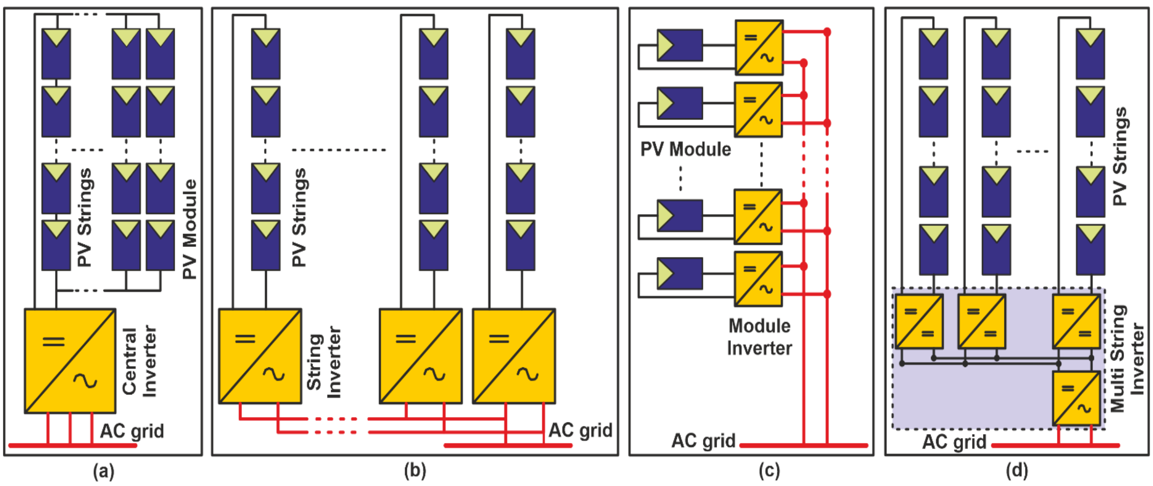

Figure 1. (a) Central (b) String (c) Module (d) Multi-String Inverter Topologies used in Solar Power Plant [8-9]

3 Monitoring and operation of the solar power plant

3.1 Monitoring of the solar power plant

Senyurt Solar Power Plant, which is located in Erzurum/Turkey, is a facility with a DC installed power of 3.36 MW and This facility consists of 3 parts, each of which is 1 MW in equal parts. There are generally two types of structuring in solar power plants established on the field, these are power plants with a string inverter and power plants with the central inverter. Although it is variable in power plants with a string inverter, it can be said that it is designed as an inverter for every 100 kW of power. In the mentioned power plant, a central inverter of 1 MW was used for each plot zone. There are 24 strings in a combiner box of 140 kW. Figure 2 shows the power flow block diagram of the Senyurt solar power plant with grid connection and central inverter structure [10]. In addition, the connection structures of the PV modules in Şenyurt Solar Power Plant are included in Figure 2. This structure is converted to DC-AC by means of an inverter, and electricity generation is realized by adjusting it to the level of 34.5 kV, which is the city grid, with the help of a transformer with a power of 1250 kVA. In addition, many data such as production, consumption radiation values, air conditions can be monitored instantly from the SCADA system, which is installed in the power plant.

In order to monitor the power generation obtained from Şenyurt solar power plant instantly, radiation, cell temperature, wind and ambient temperature sensors are used. Figure 3a shows the solar irradiance, PV cell temperature, air temperature and wind speed values. Figure 3b shows the power generation values of the SPP for one day. The data in Figure 3a-b are obtained in clear air without clouds. The distribution of solar radiation is quite smooth. At the same time, the temperature of the PV panel and the ambient temperature is quite regular. Wind speed varies considerably. However, in general, the radiation and cell temperature values, which significantly affect the production of the SPP, and the power generation value is in harmony. However, such smooth power generation values cannot always be achieved. Some production losses occur on days when the solar radiation is largely varying, and on sunny days when the cell temperature increases too much. In addition, the shading on the PV panels and the blocking of the surface of the PV panels as a result of snowfall are other important parameters affecting the production of the SPP. At the same time, the power generation value of SPP is not realized in any power cut on the grid side in power plants that have a central inverter structure due to their nature. In Figure 4a-b, it is seen that the power generation value of the SPP suddenly becomes zero due to the interruption on the electricity grid side.

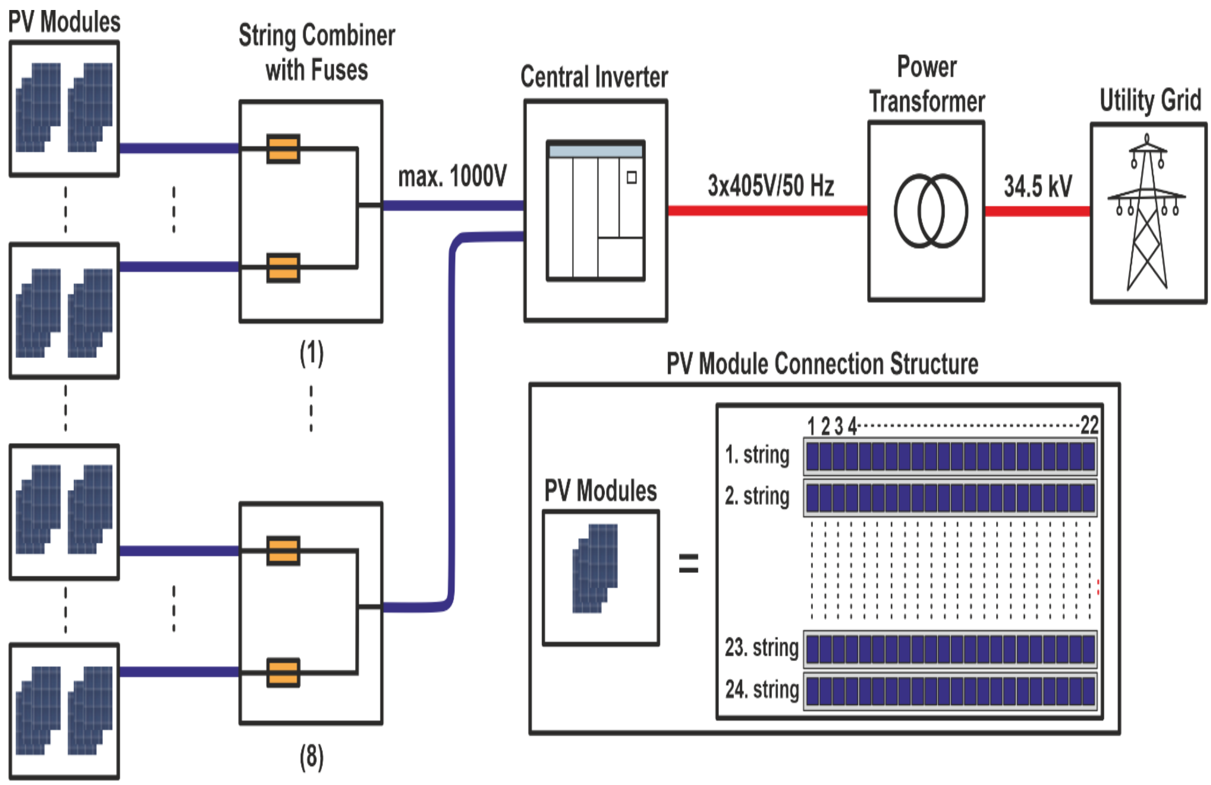

Figure 2. (a) Power flow diagram of the Senyurt Solar Power Plant [10]

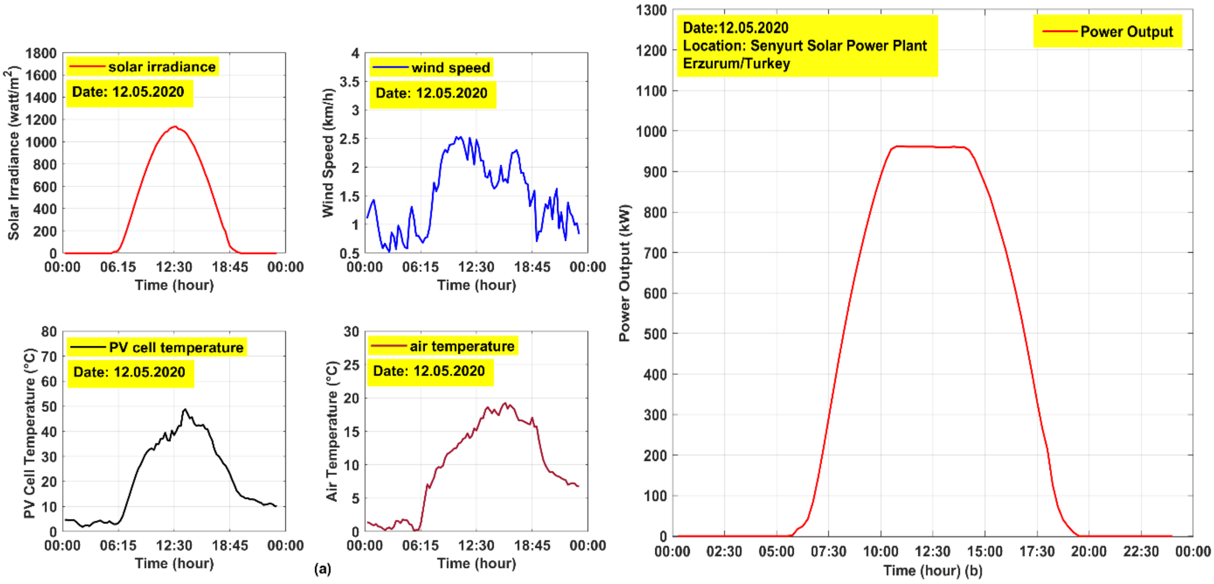

Figure 3. (a) Values obtained from the sensors, (b) One-day power generation value of a solar power plant

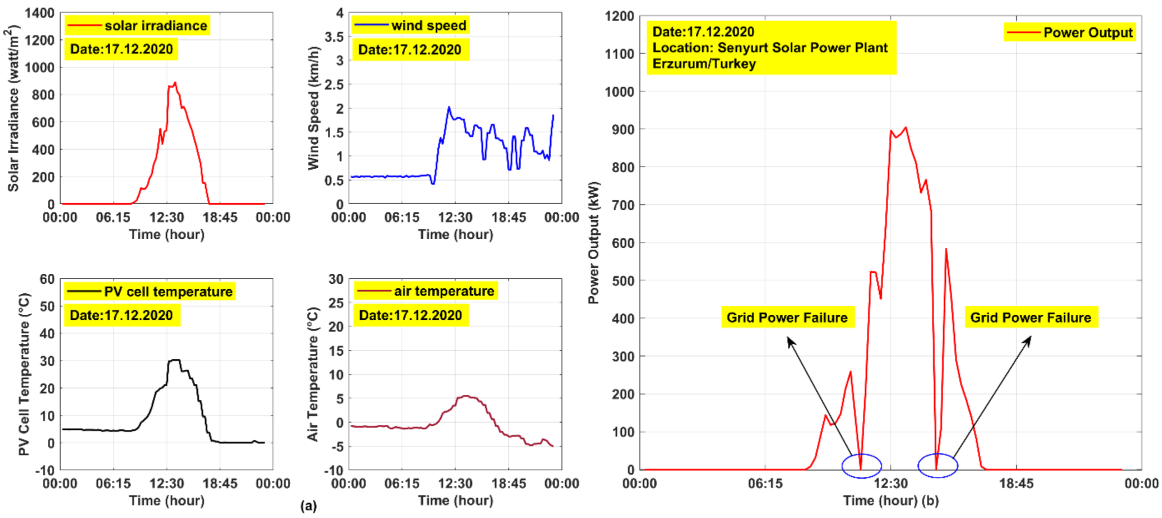

Figure 4. (a) Values obtained from the sensors, (b) Power generation on a grid power failure day

3.2 Operation of the solar power plant

The main goal of maintenance and repair in solar power plants is to keep the production of the system at an optimum level continuously. Studies in this context should be carried out on a daily, 6-month and annual basis. The works carried out in the solar PV plant can be listed as follows.

- I-V characteristic measurements
- Thermal imaging (Hot-Spot Failure Detection)
- Cleaning of PV panel dirtiness
- Weed cleaning, Snow Cleaning
- High voltage installation control and operating
- Transformer maintenance
- SCADA system control
- PV string measurements
- Weather station maintenance
- MC4 connector controls
- Measurement and controls for inverter
- Grounding measurements
- Lightning protection system measurement
- Construction torque measurements
- Low voltage electrical installation measurements
- Camera system (remote monitoring of SPP) control
- Relay maintenance
- Control of the power generation value of SPP
- Labeling operations

One of these important works is the snow cleaning of the PV panels and it shown in Figure 5a. Although low temperature plays a major role in increasing the efficiency of photovoltaic panels, this situation causes the snow accumulated on the panel to not melt after the snowfall and to freeze and stick on it.

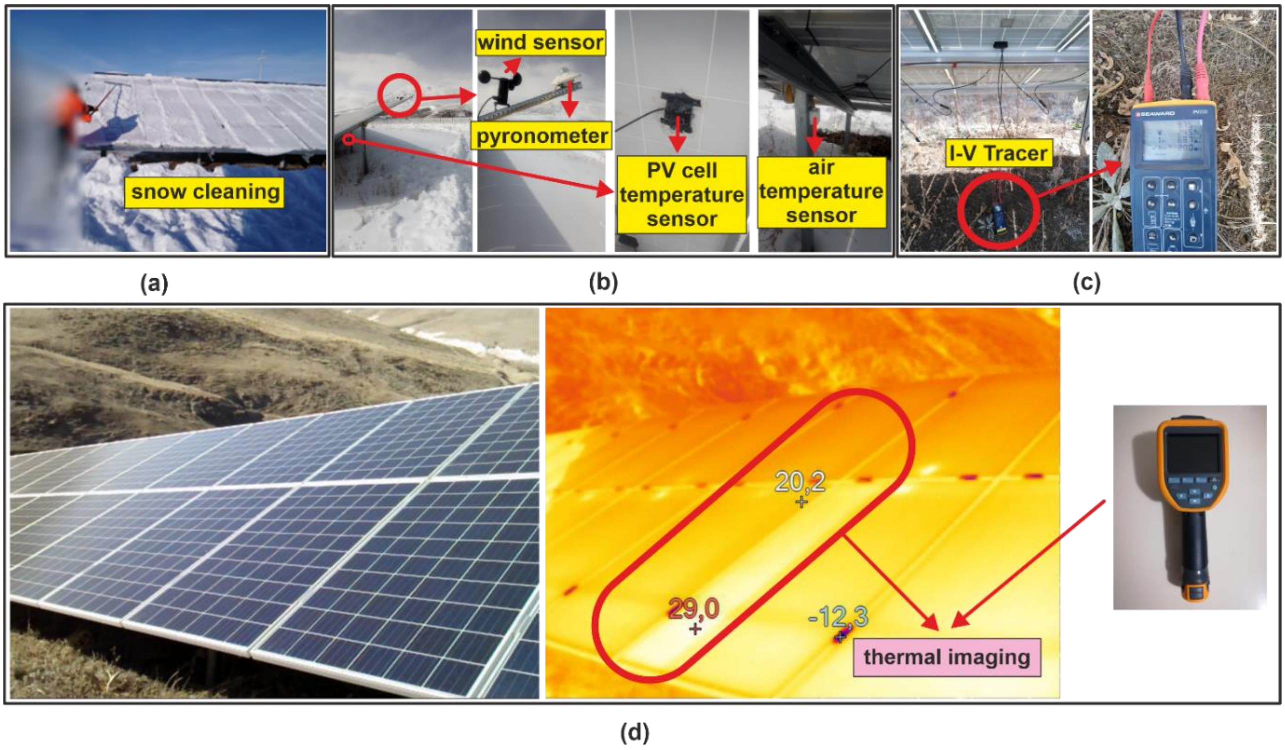

Figure 5. (a) Snow Cleaning (b) Solar Power Plant Sensors c) PV I-V tracer (d) PV Thermal Imaging

It is aimed that the accumulation of snow, which remains as frost on it, is first thinned and the sunlight penetrates the panels, even if a little, and the panel starts production and generates heat. Special floor mats used in this process should be used with care and should be worked without damaging the panels. If the works are done correctly, the snow on the ground will increase the power generation of the power plant above its normal level with the albedo effect. The sensors in the weather station shown in Figure 5b should be maintained frequently and should work correctly. The data produced by these sensors are recorded and instantaneous values can be seen by remotely reading the data. Thanks to the data seen from the sensors, the energy actually produced and the energy that must be realized is compared and it is understood whether there is any problem. I-V measurements shown in Figure 5c should be made at least once a year. These measurements are made on the basis of strings and the Maximum Power Point (MPP) status of the strings is observed by creating an I-V chart. In the strings with defects in the I-V graph, if there is no DC fuse, broken cable or the panels are dirty, thermal measurements can be made as shown in Figure 5d. Thermal measurements are made with hand thermal or drone with a thermal camera. Figure 5d shows the irregularity of the temperature distribution at different points of the PV panel. As a result of thermal measurements, micro-cracks, cell failures and by-pass diode failures in photovoltaic panels are detected.

4 Conclusion

In this study, real-time monitoring, control and operation of the power generation of Şenyurt (Erzurum/Turkey) SPP with a three-phase central inverter topology is discussed. The study includes detailed information about the power monitoring, control and operation procedures of the SPP. At the same time, with the SCADA system in the SPP, solar radiation affecting the production of the SPP, temperature value of the PV panel cell, air temperature and wind speed values were obtained. In addition to all these, visuals about thermal imaging for hot zone faults of solar energy panels and I-V characteristic measurement of PV panels were given. Finally, the daily power generation value of the solar power plant was monitored and it was evaluated whether there was any problem with the power generation values.

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Conflict of interest

The authors declare that there is no conflict of interest.

Similarity rate (iThenticate): %5

References

[1] G. Y. Cao, J. Gao, T. Ermolieva, X. Xu and E. Rovenskaya, Societal dimension of energy consumption-exploring environmental inequality in China. Institute for Applied Systems Analysis, 8(2), 59-65, 2017. https://doi.org/10.5430/rwe.v8n2p66

[2] F. Birol, et. al., World energy outlook 2020, International Energy Agency, 1-464, 2020.

[3] Y. Gao, X. Gao and X. Zhang. The 2 ℃ global temperature target and evolution of the long-term goal of addressing climate change-from the United Nations framework convention on climate change to the Paris Agreement. Engineering, 3(2), 272-278, 2017. https://doi.org/10.1016/J.ENG.2017.01.022

[4] B. Burger, D. Kranzer, Extreme high efficiency PV-power converters. In: 13th European conference on power electronics and applications, pp. 1-13, Barcelona, Spain, 8-10 September 2009: IEEE.

[5] M. Saidan, A. G. Albaali, E. Alasis and J. K. Kaldellis, Experimental Study on the Effect of Dust Deposition on Solar Photovoltaic Panels in Desert Environment, Renewable Energy, 92, 499-505, 2016. https://doi.org/10.1016/j.renene.2016.02.031

[6] IRENA (2019), Renewable Power Generation Costs in 2018, International Renewable Energy Agency, Abu Dhabi, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/May/IRENA_Renewable-Power-Generations-Costs-in-2018.pdf, Accessed 10 May 2021.

[7] Solar Energy. https://www.irena.org/solar, Accessed 29 April 2021.

[8] L. Hassaine, E. OLias, J. Quintero and V. Salas, Overview of power inverter topologies and control structures for grid connected photovoltaic systems. Renewable and Sustainable Energy Reviews, 30, 796-807, 2014. https://doi.org/10.1016/j.rser.2013.11.005

[9] T. K. S. Freddy and N. A. Rahim, Photovoltaic Inverter Topologies for Grid Integration Applications, in Advances in Solar Photovoltaic Power Plants, Springer-Verlag Berlin Heidelberg, 2016, ch. 2, pp. 15-23. https://doi.org/10.1007/978-3-662-50521- 2_2

[10] Sunny Central 1000CP XT. https://files.sma.de/downloads/SC1000CP-DEN1751-V23web.pdf, Accessed 25 April 2021.