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Research Article

An Integrated PV Farm to the Unified Power Flow Controller for Electrical Power System Stability

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Abstract: Scientists have approved the significant contributions of photovoltaic (PV) to the unified power flow controller (UPFC). It is obvious that PV has made a significant contribution to power quality issues (PQI) and stability in practical voltage sag/swell and harmonic. In addition to that, recent interest in the integration of PV into the electrical power system (EPS) poses an UPFC based on the maximum power point tracker (MPPT) technique to enhance stability. In this regard, the MPPT technique function is to achieve peak power in the best way possible. Thus, The PV-UPFC technology has a huge effect on PQI at the EPS. This article has felicitously modeled the EPS with the PV-UPFC array. Moreover, the 400.0-kW PV-UPFC farm is composed of four PV arrays that gain each one with a peak of 100.0-kW at 1k W/m^2sun irradiance. it is important to note that a single PV-UPFC array block is made of sixty-four parallel strings. Foremove, each PV-UPFC array string has five Sun-Power SPR/315E interfaced in series utilizing MATLAB-Simulation.

Keywords: Photovoltaic; Electrical Power System; UPFC; MPPT Technique; Power Quality Issues; Stability

1. Introduction

A proliferation of energy storage systems (ESS) has been observed in recent years. The photovoltaic-unified power flow controller (PV-UPFC) technology can be determined as one of the most serious challenges in the electrical power system (EPS) aspect [1-4]. In addition to that, PV-UPFC technology can be an important part of increasing renewable energy's contribution to electrical utilities (EU). In this direction, increased competition between the EU makes the PV-UPFC technology fundamental for the EU to innovate [5-9]. Figure 1, illustrates the structure diagram of PV-ESS Technology. The PV-UPFC technology has a crucial principle designed to deliver electricity to the end-user demand by UE.

To reduce power quality issues (PQI), smooth functioning, and uninterrupted PQI [10]. Figure 2, illustrates the structure diagram of PV-UPFC technology with power electronic devices. Thus, efforts to establish a stable PQI in the EPSs are well succeeded. The PV-UPFC technology is one of the most encouraging energy storage system (ESS) technology for an environmentally sustainable society. The power electronic devices converter topologies, which facilitate rapid and flexible control, are frequently utilized to link ESS to the EPS [11,12]. This critical control capability lets PV-UPFC be empowered in wide-ranging EU appliances, including frequency and voltage profile, and generation, transmission, and distribution (T&Ds) deferral. The category of ESS is present in Figure 3.

In this direction, the EU-scale mentioned above, the customer-side of the EU is appealing to trade industrial, and household consumers due to their utility in lowering power-demand unstable and expanding PV-UPFC self-uptake. In a nutshell, the literature about PV-ESS and PQI strongly recommended that the concept and attainment of a PV-ESS embedded in a SAPF device to reduce PQI and produce clean energy are described in this article [13-17].

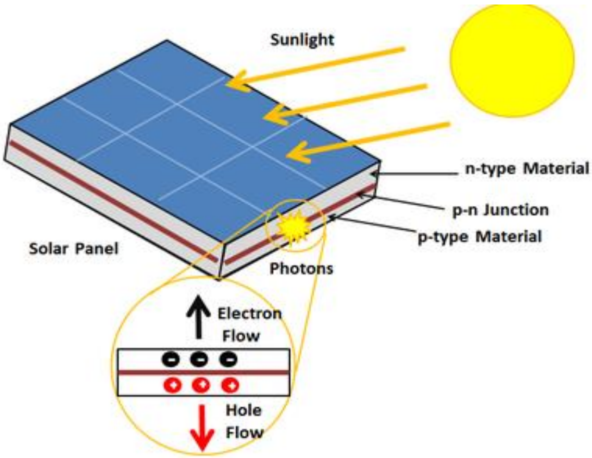

Figure 1. The structure diagram of PV-ESS Technology.

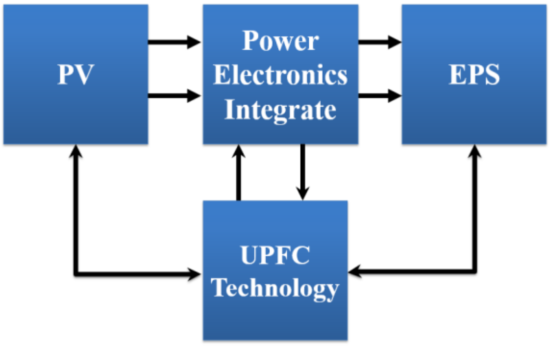

Figure 2. The structure of the PV-UPFC technology with power electronic devices [4].

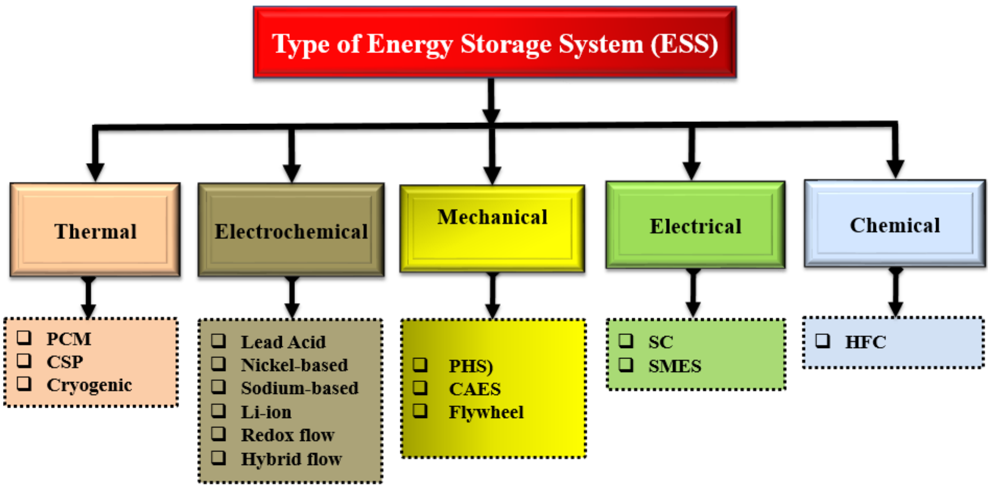

Figure 3. The category of the energy storage system.

The method utilizes a P&O technique that aims to achieve peak power points and regulates an I-V and PQI. In addition to that, Simulation-modelling is employed to interface the MPPT control technique, which is then affirmed in real-time. In this regard, different approaches are reported in the literature to address PV-ESS technology. This article investigated the optimization techniques for the mathematical model, with a concentrate on (a) the objective function utilized, (b) the model-based type, (c) the algorithm being used for parameter extraction, and (d) solar-PV-ESS panel advanced technologies [18-22]. Moreover, it provides an in-depth assessment of the numerous incorporated a number used for affirmation, comparisons with techniques, benefits, and drawbacks affiliated with each method concerning the parameter identification platform, thoughtful examination of each technique at S-T-C, and inconstant irradiance scenario [23-26].

Moreover, a serious evaluation of a particular to manage of algorithms based on target operation amount is performed. Moreover, this article's contribution is to investigate and demonstrate the properties of MPPT techniques related to PV-UPFC modeling, and it serves as a powerful technique for scientists who work in the area of PV-UPFC model parameters. EPS simulation consists of representative 25.0 kV feeders as well as 120.0 kV equivalent T&Ds. A 3-phase VSC transposes the 0.5k V-DC into 0.26k V-AC and sustains unity for PF purposes. In addition to that, the 400.0 kVA 260.0 V, and 25.0 kV 3-phase transformer was utilized to integrate the VSC into the EPS.

In the following sections, the article illustrates the next parts of the article. **Section 2** deals with the PV-UPFC and its properties. **Section 3** demonstrates the solar-PV-ESS cell materials on performance. **Section 4** indicates the model of PV-UPFC integration for EPS. **Section 5** shows the Simulation Parameters of PV-UPFC. **Section 6** illustrates the result and discussion. **Section 7** shows the discussed conclusions of the article.

2. PV-UPFC and its properties

In this section, the PV-UPFC module is created of a series or even parallel interfaced into PV-UPFC cells, each of which has a high ability to generate EU. Moreover, PV-UPFC modules are integrated into several arrays to produce high PQ. Figure 4, illustrates the transformation from the PV-ESS cell, PV-ESS module, and PV-ESS array.

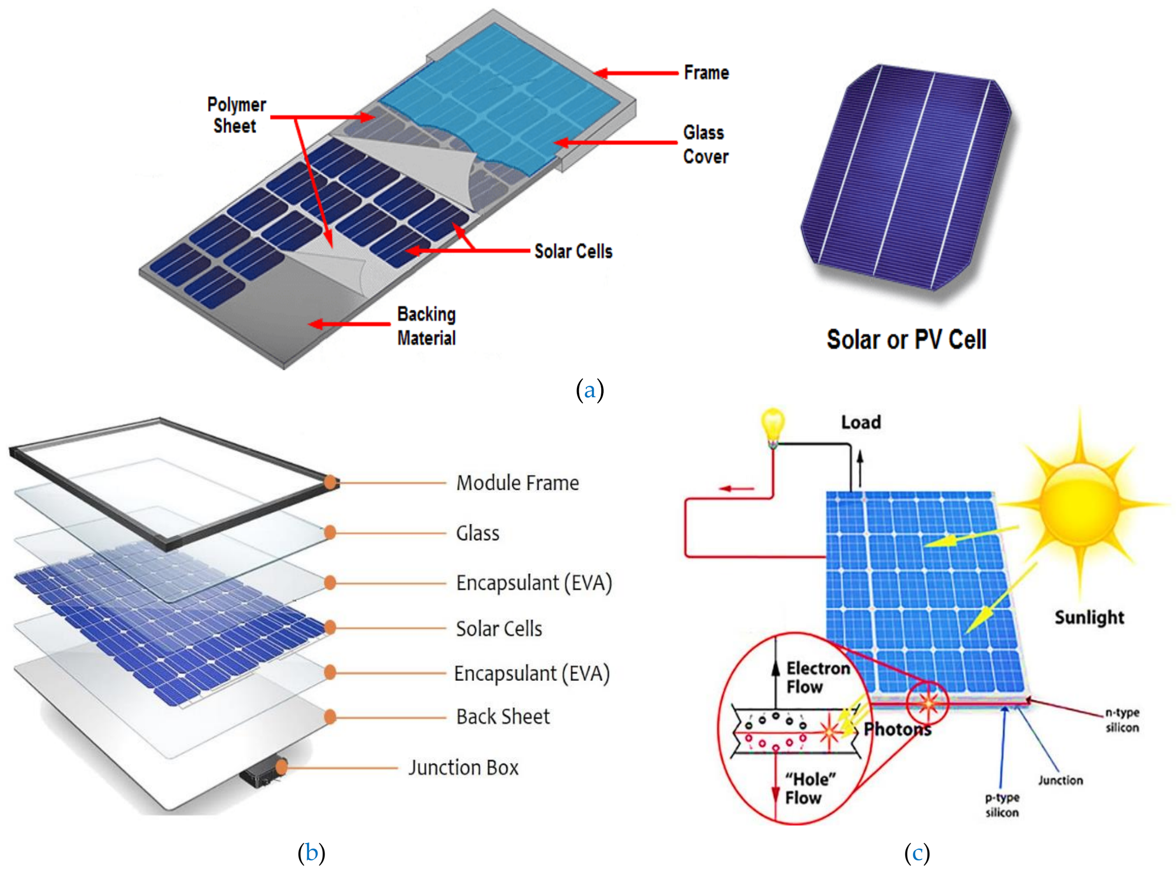

Figure 4. The transformation from PV-ESS cell, PV-ESS module, and PV-ESS array.

It is worth noting that in solar-PV-ESS panels, irradiation determines based on the short-circuit current and temperature °C, and then determines the open-circuit-voltage [27-31]. As a demonstration of its significance, Figure 5, illustrates the V-I properties of an ideal solar PV-ESS panel at various insolation levels and temperature levels.

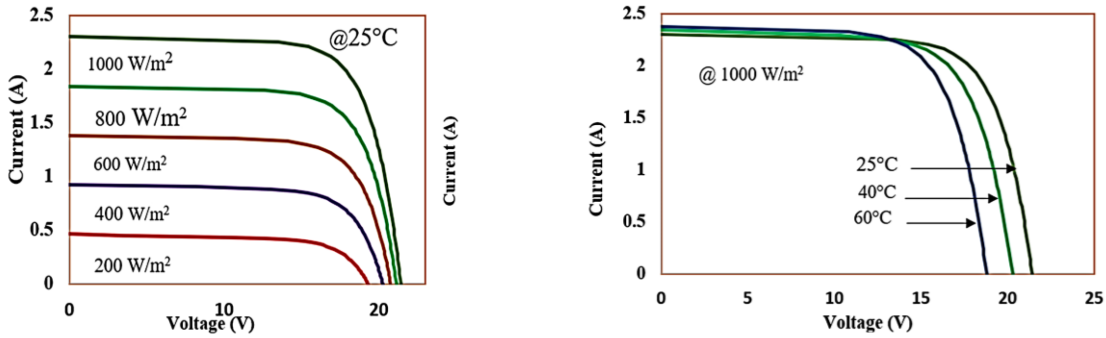

Figure 5. The I-V turns of the PV-ESS panel during several irradiances at a constant temperature

From the properties curves aspect including 1000 W/m^2, 800 W/m^2, 600 W/m^2, 400 W/m^2, and 200 W/m^2. The PV-UPFC performance is largely determined by both of these nature-controlled parameters. Therefore, PV-ESS modeling should take this into account during MATLAB-Simulation [32-35].

3. PV-UPFC cell materials on performance

In this section, the materials of PV-ESS needed that is equivalent to 1st, 2nd, and third-21th-generation PV-UPFC cells are the following silicon, Cd Te, and nanocrystal-organic, polymer-materials. Over 90.0% of today's PV-UPFC are silicon-based first-generation types with a 29.0% efficiency43 with single-crystalline PV-ESS panels achieving 14.0% to 17.5% conversion efficiency and polycrystalline solar-PV-ESS cells achieving 12.0% to 14.0% efficiency. The polycrystalline solar-PV-ESS cell is more economical and stronger than the monocrystalline type [36-39].

Furthermore, thin-film cells will achieve approximately 9.0% to 12.0% efficiency with CIGS and Cd Te materials. There is an increase in efficiency combined with a reduction in cost with these 3-generation solar-PV-ESS cells. In addition to being economical, DSSCs have poor sunlight absorption capabilities; while mass-producing nano-cells is complicated. In the same direction, perovskites are the only 3-generation solar cells that are promising [40-46]. As shown Table 1. indicates different solar-PV-ESS cell materials have different efficiency levels including perovskite, mono-silicon, poly- Silicon, CIGS, nano, amorphous silicon, DSSC, polymer, and CdTe.

Table 1. The different solar-PV-ESS cell materials have a different efficiency level

Num.	Name of material	Efficiency (%)
1	Perovskite	31 %
2	Mono-Silicon	14% to 17.5%
3	Poly- Silicon	12% to 14%
4	CIGS	10% to 12%
5	Nano	7% to 8%
6	Amorphous silicon	4% to 8%
7	DSSC	10%
8	Polymer	3% to 10%
9	CdTe	9% to 11%

The PV-UPFC technology can be particularly helpful for the PQI which requires sustaining EPS oscillations as its vulnerability influences the released reference indication. The performance of the PV-UPFC technology during several fault scenarios can have a positive impact on the PQI of the EPS. In addition to that, the apple of the PV-UPFC is essential to keep the PQI stable and the operation of the EU as well. In the domain of energy storage systems (ESS), the PV-UPFC technology has been considered one of the potential solutions to the future energy crisis in the EPS. Due to the high capability to guarantee adequate energy supplies based on end-user demand. Thus, the PV-UPFC technology offers excellent facilities for EPS [47-51].

In this direction, PV-UPFC technology has received special attention in academics and industry. During the discharge process, PV-UPFC technology releases electrical energy that has been stored as chemical energy. Among of many PV technology uses are EPS, ESS hybrid-ESS, UPFC, and portable electronic devices. To further elaborate the contributions, flexible simulation parameters for network strategies are used to phase, and amplitude of the voltage [52-57]. The PV-UPFC technology has become an increasingly popular renewable energy resource (RES) in the EU aspect. The manuscript also targets to focus on the power stages configuration of PV-UPFC technology supplied EPS domain.

4. Model of PV-UPFC integration for EPS

The PV-UPFC technology is widely recognized as the founder of green electricity. Part of the contribution of this manuscript is to model a 400 k-W PV-UPFC technology farm (400 kW) integrated into 25-kV EPS applying a two-stage of voltage source converter. 400-KW PV-UPFC technology output that is compatible with the EPS to PQI stability. However, evaluating the performance of PV-UPFC technology outlet power is a highly complex situation and can be difficult, because the compounds of the evaluation substantially vary among EPS [58-62]. Figure 6, presents the PV-ESS of modeling. (a) structure schematic diagram of single-diode, (b) structure schematic diagram of double-diode, and (c) structure schematic diagram of triple-diode.

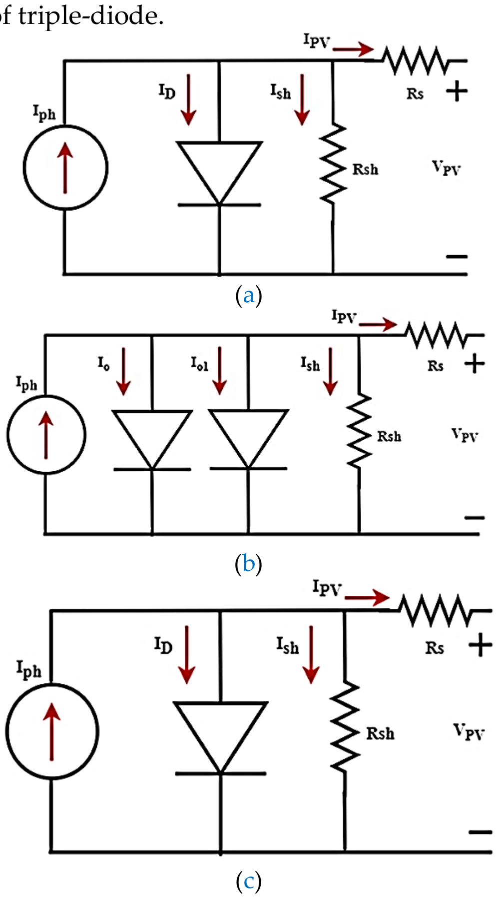

Figure 6. The solar-PV-ESS of modeling. (a) structure schematic diagram of single-diode, (b) structure schematic diagram of double-diode, and (c) structure schematic diagram of triple-diode.

Figure 6, illustrated the integration of PV-UPFC technology in the EPS, in which several elements including DC-AC converters, filters, and transformers can be amalgamated to integrate with the EPS. The EPS integrated with PV-UPFC technology has received special attention from academics. To implement the systems, a deeper understanding and detailed analysis are necessary. Detailed estimates are necessary for normal and abnormal EPS operations. In this direction, the EPS integrated with PV-UPFC technology can be operated effectively using advanced power electronics converters. By using the integrated power converter, most of the power can be extracted from the supply and put into the EPS [63,64]. It requires a DC-DC converter to boost it for various applications. PG applications require DC voltage (V_{dc}) to be converted to AC voltage (V_{ac}) by a PG side converter. Figure 7, the configuration of the EPS with PV-UPFC integration.

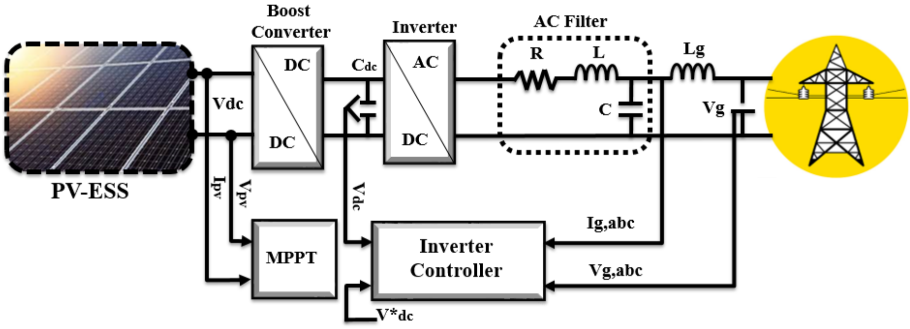

Figure 7. The configuration of the EPS with PV-UPFC integration

In this context, EPS-integrated PV-UPFC technology is increasingly being installed due to advances in power electronics. In PV-UPFC technology mode, VSI functions as a voltage source rather than a current source. This achieves efficient EPS integration through the control of inverter voltage [65,66]. However, PV-UPFC technology current supplied to the EPS can have phases with the grid fundamental voltage based on the standard of EPS integration.

5. Simulation Parameters of PV-UPFC

The article investigates the simulation parameters of PV-UPFC in EPs utilizing the MPPT control technique including EU, PV-UPFC Array, DC-DC converter, inverter, and 3-phase transformer. The potential contributors are determined by the measurements obtained at the PV-UPFC selected site. The PV-UPFC parameters can be seen in Table 2 which is implemented parameters in the MATLAB simulation software.

Table 2. HESS Parameters integrated with the EPS.

	Parameters	**Unite**	**Value**
Electrical Utility	Distribution System	kV	25
	Transmission System	kV	120
PV	Maximum Power (W)	kW	400
	Sun irradiance	W/m^2	1000
	Cells per module (Ncell)	-	96
	Short-circuit current Isc	Amps	6.14
	Open Circuit Voltage (Voc)	Volts	64.6
	Short Circuit Current (Isc)	Amps	9.34
	Maximum System Voltage	kV	1
	Operating Temperature	°C	25
DC-DC Converter	Voltage level	V	500
Inverter	Nominal Maximum voltage	V	260
	Efficiency	%	95
	Life span time	15	Years
3-phase transformer	-	kVA	400
	-	V	260
	-	kV	25

6. Result and discussion

This section discusses the interconnection of PV-ESS technology with EPS. To emphasize, EPS simulation consists of representative 25.0 kV DS feeders as well as 120.0 kV equivalent TS. A 3-phase VSC transposes the 0.5k V-DC into 0.26k V-AC and sustains unity for PF purposes. In addition to that, the 400.0 kVA 260.0 V, and 25.0 kV 3-phase transformer was utilized to integrate the VSC into the EPS. Figure. 8, illustrates 400-kW PV-UPFC farm interconnection to 25.0-kV EPS. Figure 9, presents a single simulation diagram PV-array. Figure 10, depicts DC-DC using MPPT control at PV-UPFC with EPS interconnection. Figure 11, shows the main VSC control applied to the PV- UPFC with EPS interconnection. Figure 12, illustrates the irradiances (W/m^2) applied the PV-UPFC with EPS-interconnection. Figure 13, demonstrates the main power of the PV-UPFC with EPS interconnection. Figure 14, illustrates the V/I, and PQ (kVA) of the PV-UPFC with EPS interconnection.

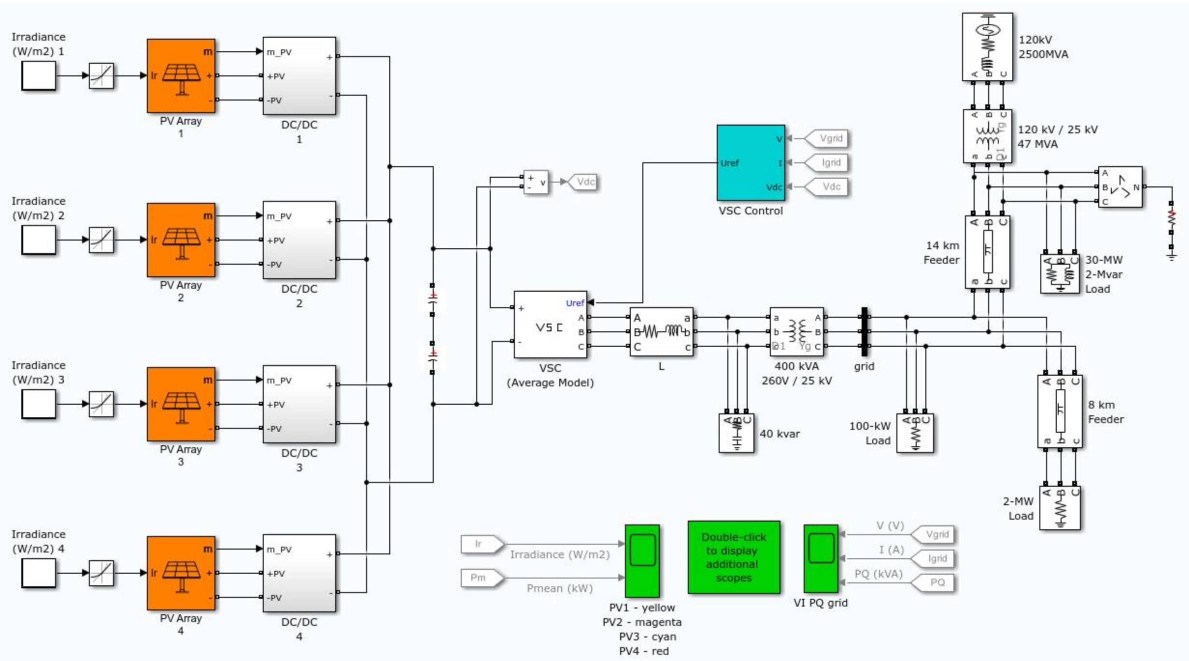

Figure 8. 400 kW PV-UPFC farm interconnection to 25.0 kV EPS.

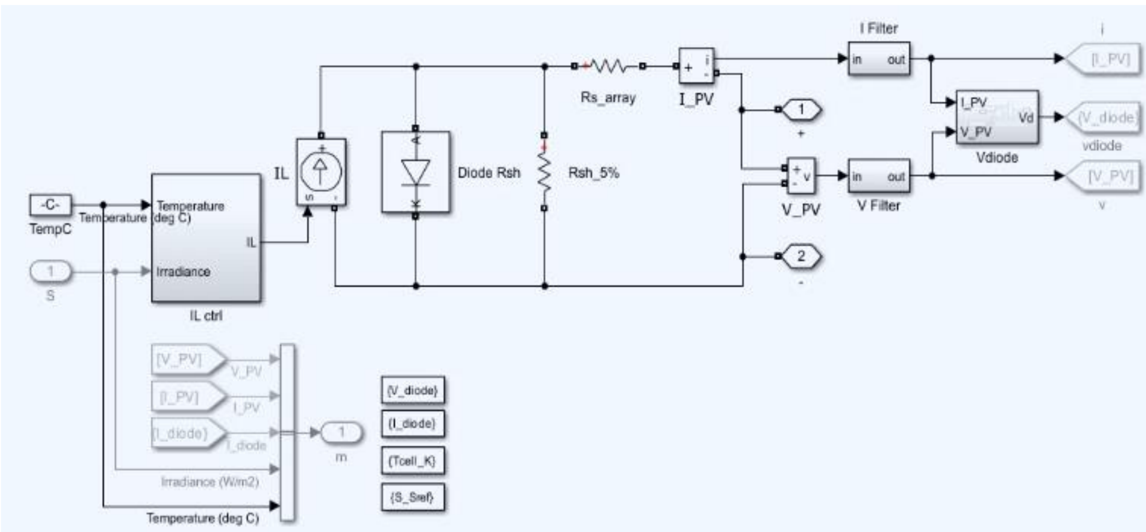

Figure 9. Single simulation diagram of PV-UPFC array.

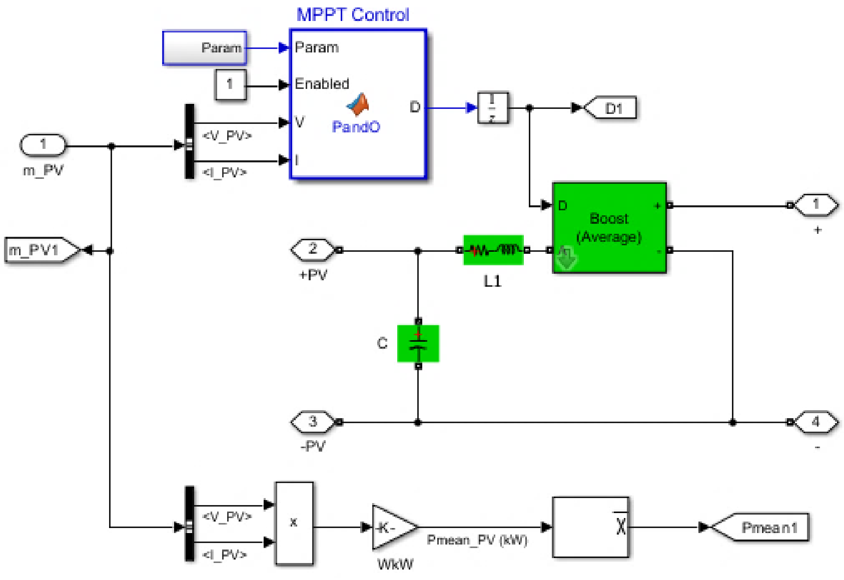

Figure 10. DC-DC converter using MPPT control at PV-UPFC with EPS-interconnection

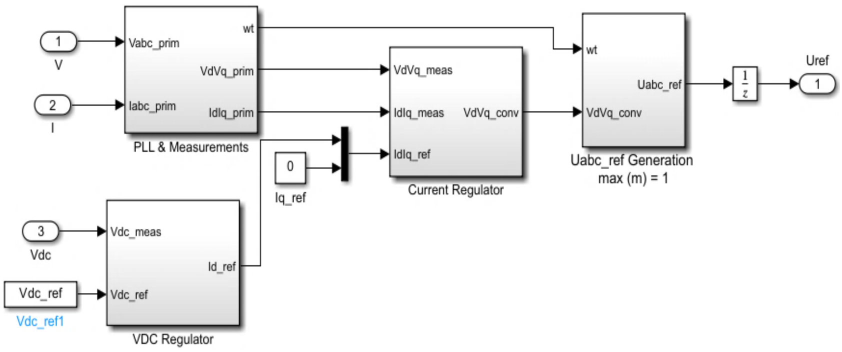

Figure 11. The main VSC control applied the PV-UPFC with EPS-interconnection.

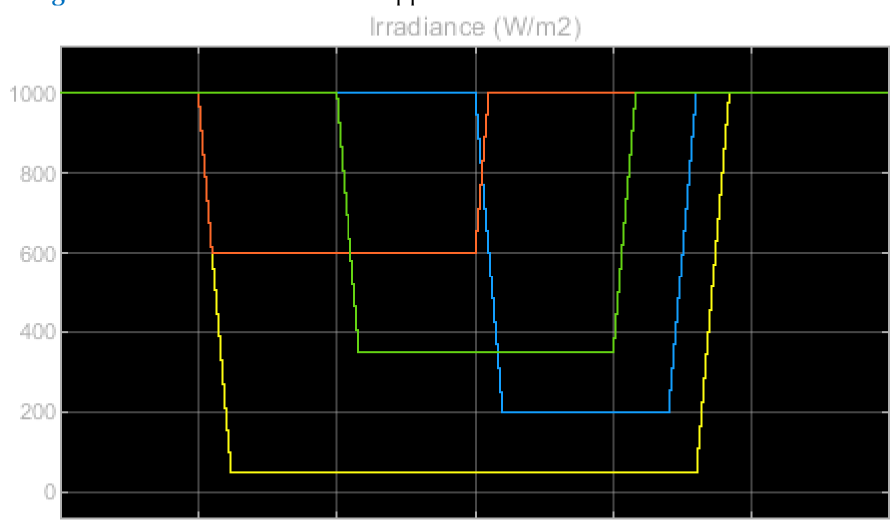

Figure 12. Irradiances (W/m^2) applied the PV-UPFC with EPS-interconnection.

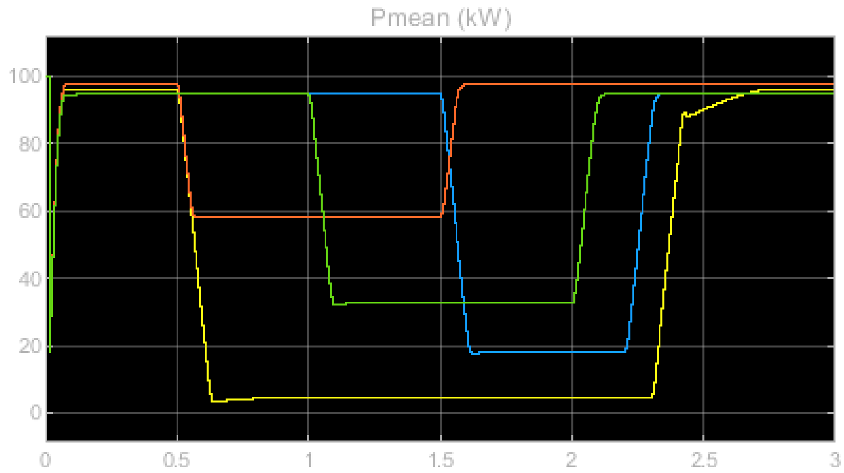

Figure 13. The main power of the PV-UPFC with EPS-interconnection

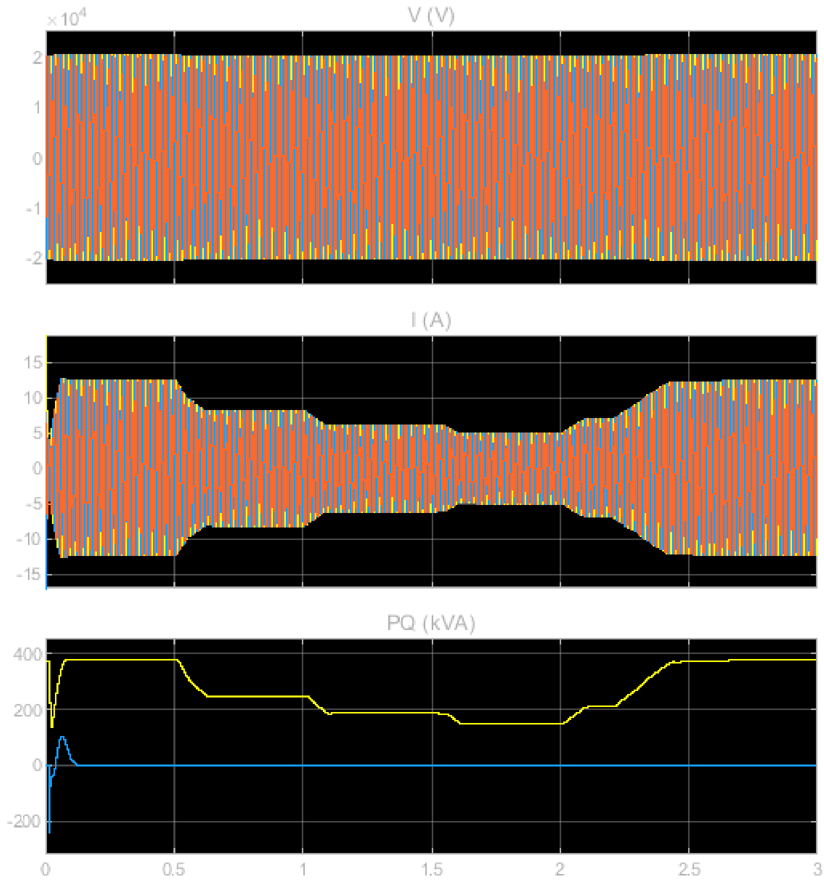

Figure 14. The voltage, current, and power quality (kVA) of the PV-UPFC with EPS interconnection.

7. Conclusion

To begin with, the technology of PV-UPFC has a significant impact on EPS interconnection. In addition to that, PV-UPFC also has made a significant contribution to the power quality issue (PQI) and the stability of the entire EU. In this regard, recent interest in the integration of PV-UPFC into the EPS poses a challenge to the stability of the system. Moreover, PV-UPFC has largely succeeded in the implementation of controller techniques using the MPPT control technique and enhanced PQI. The MPPT control objects to achieving the peak power. This article has successfully modeled and analyzed the EPS with the UPFC-interfaced PV-ESS array. Moreover, the PV-UPFC farm consists of four PV-ESS arrays provide each one with a peak of 100.0-kW at 1.0k W/m^2sun irradiance. It is worth noting that a single PV-UPFC array block is made of sixty-four parallel strings. Moreover, each PV-UPFC array string has five Sun-Power SPR/315E interfaced in series. A 3-phase VSC transposes the 0.5-k V-DC into 0.26k V-AC and sustains unity for PF purposes. In addition to that, the 400.0 kVA 260.0 V, and 25.0 kV 3-phase transformer was utilized to integrate the VSC into the EPS.

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Conflicts of Interest: The authors declare no conflict of interest.

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