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Performance improvement of fuel cell and photovoltaic system

Manjunathan Alagarsamy[1], Neera Chaudhary[2], Nithyadevi Shanmugam[3], Kannadhasan Suriyan[4], Arulmurugan Loganathan[5], Raja Manikandan[1]
[1]Department of Electronics and Communication Engineering, K. Ramakrishnan College of Technology, Trichy, Tamil Nadu, India
[2]Department of Computer Engineering, New Horizon College of Engineering, Bengaluru, Karnataka, India
[3]Department of Electronics and Communication Engineering, Dr. N.G.P. Institute of Technology, Coimbatore, Tamil Nadu, India
[4]Department of Electronics and Communication Engineering, Study World College of Engineering, Coimbatore, Tamil Nadu, India
[5]Department of Electronics and Communication Engineering, Bannari Amman Institute of Technology, Sathyamangalam, Tamil Nadu, India

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ABSTRACT

This article considers and studies a hybrid energy storage system as a potential replacement for a utility grid. It also examines its organisational structure. The hybrid energy storage technology is used to ensure a constant supply of convenient grid electricity that is sufficient to handle changing power spikes. Batteries are used to stabilise the surges with measurable variation, whereas a massive capacitor is utilised to stabilise the surges with fast variation. In isolated areas where connecting to the main utility grid is impractical, standalone renewable generation may provide the advantage of a reduced operational cost as well as a reduction in protection fees. In order to encourage non-conventional power production in the overall renewable energy system, advancements in solid oxide fuel-cell technology and solar photovoltaic (PV) technology have also been made. Grid-coupled solar PV energy producing systems are being extensively used worldwide, and solar PV modules are increasingly being used in residential applications linked to the electrical grid.

Corresponding Author:

Manjunathan Alagarsamy
Department of Electronics and Communication Engineering, K. Ramakrishnan College of Technology
Trichy, Tamil Nadu 621112, India
Email: manjunathankrct@gmail.com

1. INTRODUCTION

Reliable, energy-efficient renewable-based power systems have been developed as a result of the decline in conventional energy sources including firewood, gasoline, and other related materials. The cost of petroleum has fallen to an incredibly low level as a result of the employment of various power sources. In isolated areas where there is no link to the main utility grid, standalone renewable producing may have the advantage of simplified operations and cheaper maintenance costs. It is essential to have a hybrid power system that combines solar photovoltaic (PV) with solid oxide fuel cells (SOFC) since the environment of load demand is always changing and renewable power sources are becoming more significant. A kind of energy management strategy is required to maintain the power contribution between the batteries and super capacitors. To maintain a steady and smooth power flow, this is done. Currently, it seems that the battery storage system can handle both the power production and the load demand variations [1] in the applications of the current life power system. In standalone solar PV systems, lead acid batteries are commonly used to store energy [2]–[6].

While electricity producing and distribution businesses are still having trouble competing, interest in renewable and alternative energy sources is rising. Due to this disagreement, companies are experiencing difficulties, starting with consumers who are in support of improving the quality of electricity and using greener electrical energy. Additionally, as legislation is being developed that aims to support sustainable renewable energy inventions and the fact that the world's stockpiles of firewood are decreasing, we are compelled to look for new ways to generate electricity. This is due to new legislation that supports sustainable energy solutions. Utility grid systems are one of the individual resolutions that are now being considered [1], [7]–[10].

Our houses and businesses are powered by electrical network systems that combine a number of unusual power sources. Among the technologies employed are the wind turbines, solar PV cells, SOFC, hydro turbines, and batteries that they protect. In order to facilitate usage of the arrangement, they are positioned such that they lie on the ground and linked with connections to the major power grids. Additionally, they are placed in a place that will make it easier for someone to utilise the arrangement. Power electronics are being used to facilitate connecting to the low voltage circulation system. Accordingly, utility grids are desired for a variety of reasons, one of which is that they are handy. The main cause of this is because they utilise alternative energy sources, the majority of which have been proved to be far more efficient than traditional power generating methods and to have a lower overall environmental effect. Utility grids are much more resourceful and ecologically benign than their conventional counterparts. This is because the transmission losses necessary for electrical energy are proportionately reduced as they come closer to the area where they are supposed to supply energy. It may also be considered that they are heading towards the site where they will be delivering it as they move in that direction. Finally, plans are being made to change a utility grid so that it can meet the requirements of the community it is designed to serve [11]–[15].

Currently, a group is investigating the possibility that certain organisms have an addiction to power grids. Although the operation of a utility grid may be fairly well understood, the setup itself cannot be considered to be complete. Although there are many different sources supporting the existence of a utility grid, the system's effectiveness and applicability are still subject to change. Utility grid studies are sensitive since they model the arrangement in each specific situation and look into the most effective ways to set up a suitable control mechanism. Currently, several research organisations spread over the universe are looking at the viability of utility grids as well as any possible advantages they could have. One of the groups' representatives presented evidence in support of the use of technology to increase energy security. This representation is based on a minimal control consortium for electric reliability, which obtains finance as a component via a partnership with many commercial enterprises. The collaboration is able to buy the required chemicals thanks to this money. The key to raising public awareness of the dependability of the electrical grid is the development of a physically sound and financially sound barrier that connects it to a greater capacity power system. The cornerstone of the whole organisation is this idea [16]–[20].

This paper's goal is to systematise the effort being put out to further the creation of such a representation. In terms of both the production and distribution of power, utility grids are a relatively recent concept. Researchers have several challenges as a result of the lack of lucrative power simulators that can integrate alternative and non-conventional sources, the most important of which is the challenge of assessing the utility of grids on a power systems stage. This is because several other challenges have also been faced by researchers. The case modelling of inverters has evolved into a new important work in addition to the anomalies that seem to be connected to power electronics. This article's goal is to provide a picture of a utility grid that combines a SOFC with a solar PV system. With the intention of organising the argument analysis for the enhancement of the auxiliary illustration, it is proposed that the work completed in this revision's effort. The long-term objective of this project is the construction of a highly precise and thorough representation of a utility grid. This will provide a thorough grasp of how utility grids work. This study uses Simulink-based MATLAB simulations to build a block position for power electronics-based SOFC devices coupled with solar PV [21]–[26].

2. POWER MODEL

When it comes to the intricacies of resource development and the power electronics that go along with it, a grid's technical information is correct. In Figure 1, the proto model's global setup is shown. It will be discussed how to link the systems to an effective inverter design and how to connect the main source and electric load to them.

After a utility grid was assessed using standards that were compatible with the physical certainty of such systems, a feasible arrangement was finally developed for their inclusion. The exposed Simulink model representation is shown in Figure 2. A solar PV system with a SOFC setup may be linked to the grid and the inverter's direction by using coordinated DC-DC converters.

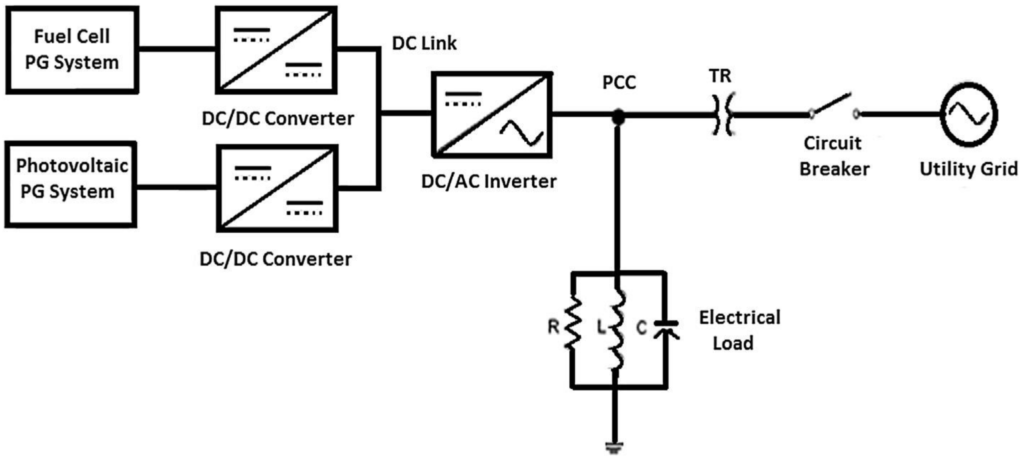

Figure 1. Block diagram of grid

Fuel cells can regulate temperatures between 650 °C and 1000 °C by using an O2 ion conductor as the electrolyte. Figure 3 shows how the use of hydrogen, CO, and methane as fuels is made possible by the O2 ions, while the oxidant, O2, is provided by the environment. The ceramic composite that makes up a contemporary SOFC is doped with lanthanum, manganese, and strontium as illustrated in Figure 4. The electrolyte of a SOFC is a ceramic-metallic composition. The SOFC is an example of a solid-state structure, hence a range of various designs may have an impact on it.

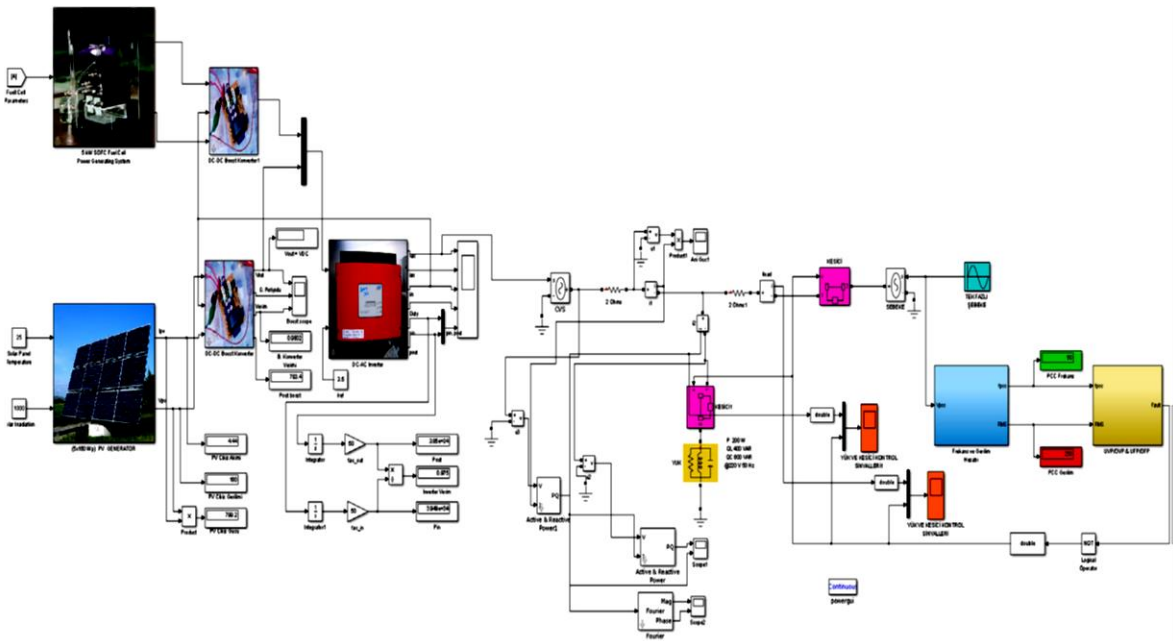

Figure 2. SOFC with solar PV

A depiction of a SOFC's output voltage waveform is shown in Figure 5. By changing the input parameters of the model of the SOFC that was built, the output of the SOFC may be altered. Figure 6 shows the power generated at the start of the SOFC. The SOFC is now the greatest choice for producing electricity and giving back. In this case, the method of connecting to the grid and the conversion of direct current to alternating current are connected.

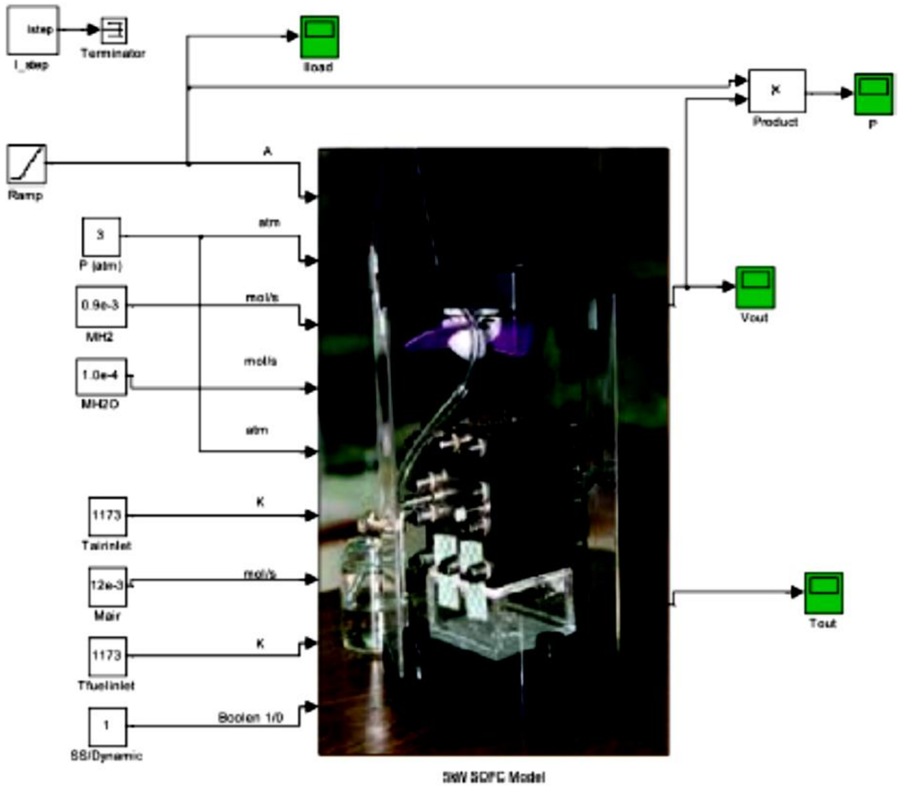

Figure 3. SOFC MATLAB/Simulink model

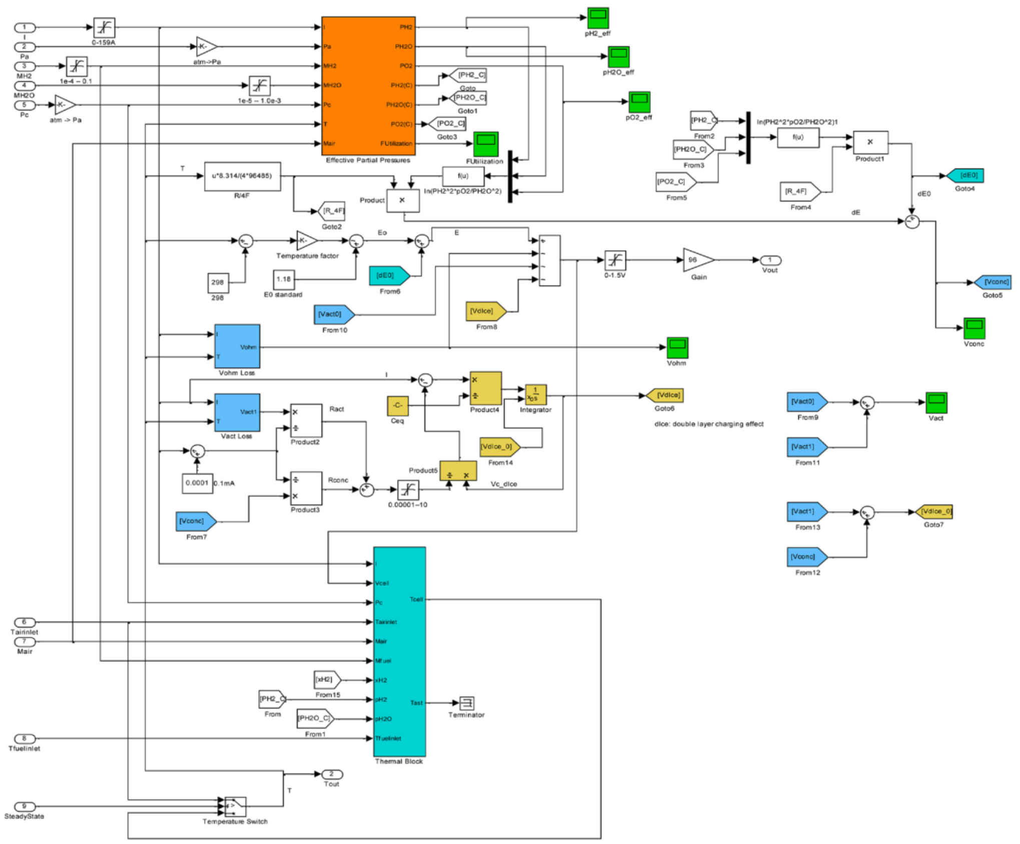

Figure 4. SOFC MATLAB/Simulink representation

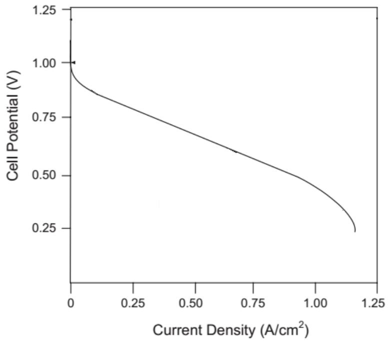

Figure 5. Output voltage of the SOFC

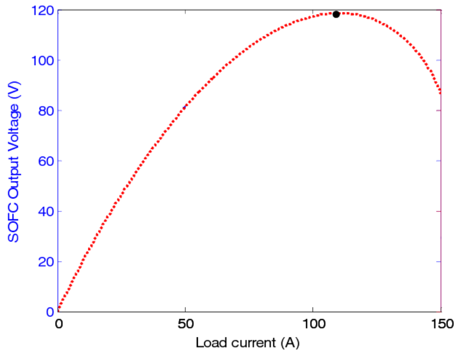

Figure 6. Output power of SOFC

A solar PV unit's input parameter created by Simulink might be used to restrict the input interface shown in Figure 7. In combination with the creation of output parameters for a solar PV system, these qualities will be assessed by a developed illustration. Figure 8 displays a depiction of a solar PV unit that was created. Utilising MATLAB/Simulink, this was produced. The representation's input parameters include the module's temperature as well as its isolation, and it uses these input values to generate the output current and voltage of the solar PV element.

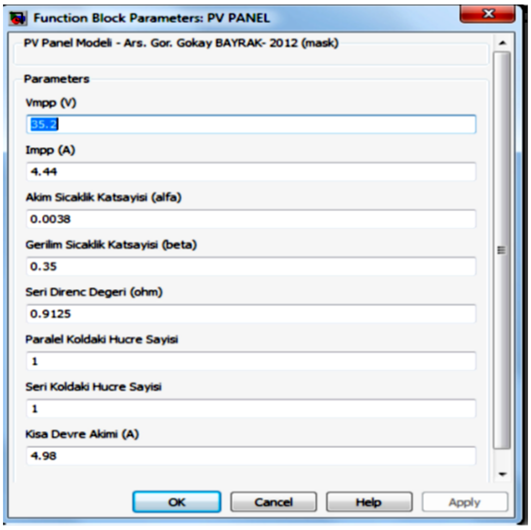

Figure 7. Input parameters of solar PV module

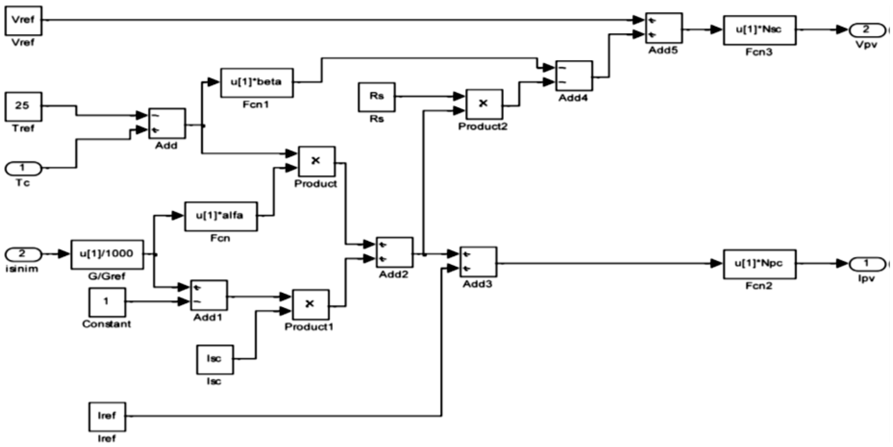

Figure 8. Simulink subsystem of solar PV module

Figure 9 depicts these crucial arrangements as a representation, and they are now being put into reality. While upholding power standards, the system generates precise current and voltage. The voltage, current, and power of a solar PV unit under typical working circumstances are shown in Figure 10. These are, respectively, 250 ºC and 1000 watts per square metre.

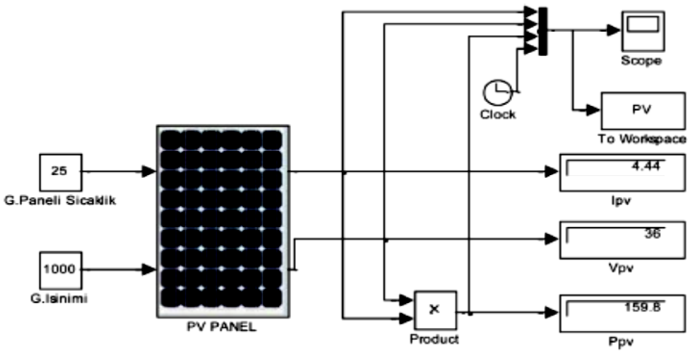

Figure 9. Simulink representation of solar PV module with isolation module temperature

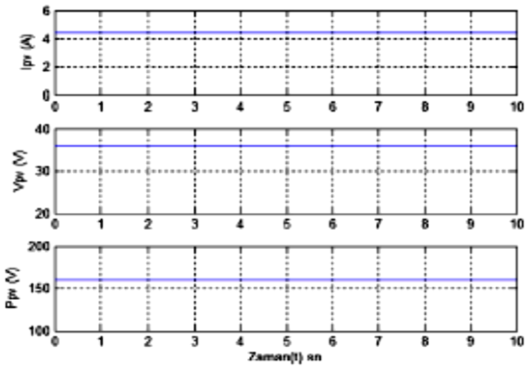

Figure 10. Solar PV module output voltage, current and power

Using the created model, the current-voltage curve for solar PV modules was produced, and it is shown in Figure 11 together with the curve. Verify that the voltage and short-circuit current values of the solar PV module are 43.3 V and 4.98 A, respectively, using the current-voltage curve. The improved solar PV module was examined for temperature change in solitary test circumstances. As a result, in addition to the curves illustrated in Figure 12, the representation also allows for the determination of the I-V curves of solar PV modules under various isolation standards.

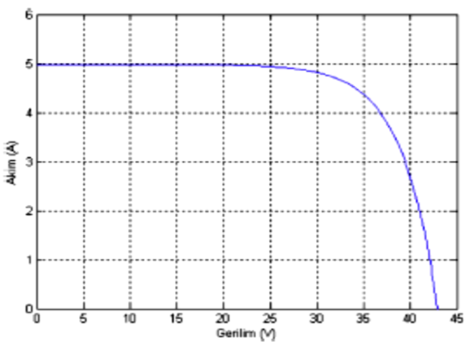

Figure 11. Solar PV module I-V curve

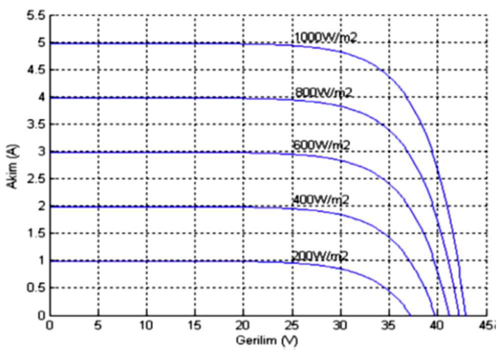

Figure 12. Solar PV module I-V curves under different isolation values

Significant changes are made to the existing solar PV component, however the isolation is modified more as a consequence of these changes than the voltage is. The contradiction between this condition and the inquiry module's temperature change makes it a precise condition. These possibilities are shown in Figure 13, and it should be noticed that the current shift is far more substantial than the voltage change. A solar PV generator model should next be built after correctly depicting solar PV modules. The entire number of solar PV components that are either linked in series or parallel with one another makes up the depiction of a solar PV generator model that is depicted in Figure 14.

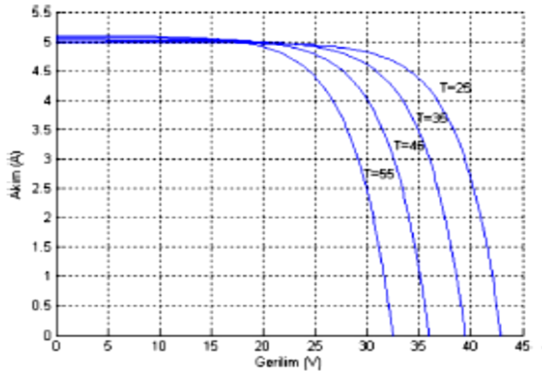

Figure 13. Solar PV module I-V curves under different module temperature values

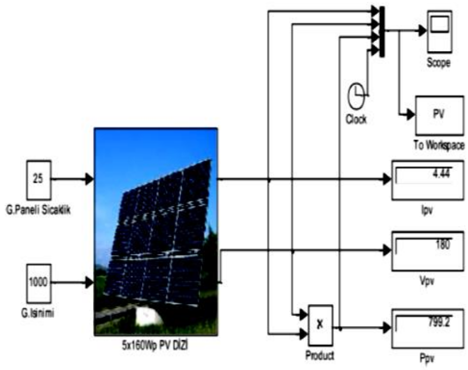

Figure 14. Solar PV generator model

3. RESULTS AND DISCUSSION

DC energy is produced by both solar PV system and SOFC models, and this DC power should be used as an energy input into the proper inverter. A depiction of a DC-DC converter like the one in Figure 15 will need to be created in order to achieve this aim. Both the SOFC model and the solar PV yield will utilise this illustration. The findings are given and emphasised in Figure 16 after the inputs and reference current have been considered.

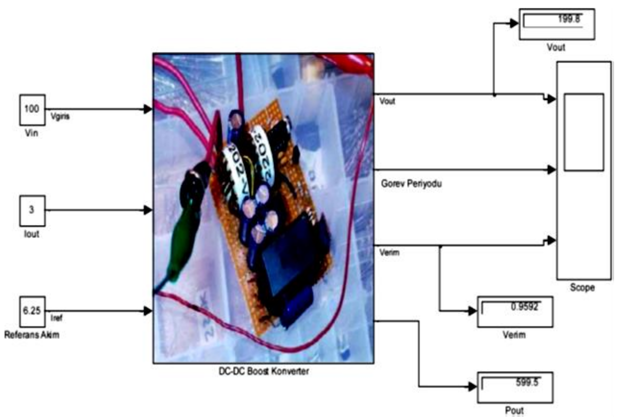

Figure 15. Simulink DC/DC converter model

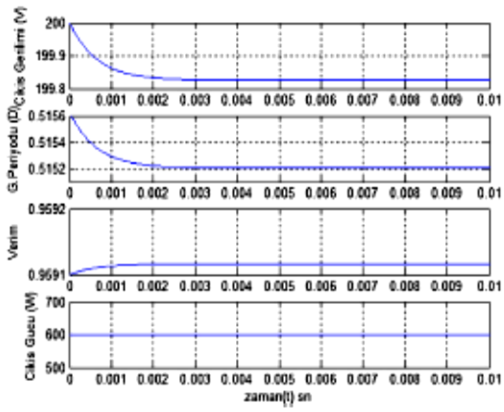

Figure 16. DC/DC converter output waveform

It is proposed that a representation of an inverter be developed for the purpose of connecting a SOFC system as well as a PV system to the utility grid. Figure 17 provides a visual representation of the primary configuration of the developed DC-AC inverter. Figure 18 is able to convey alternating current with a potential inverter thanks to this capability. These factors are furthermore suitable for application in the relationship with hybrid power generation systems with utility grids. Figure 19 also displays the duty cycle of the converter in addition to the input I of the device.

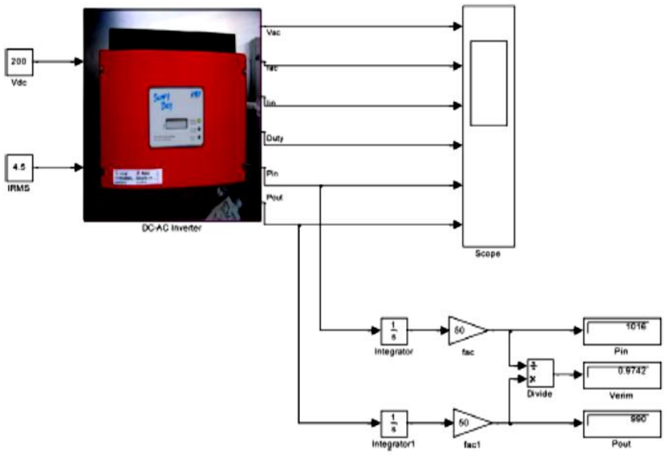

Figure 17. DC/AC inverter model

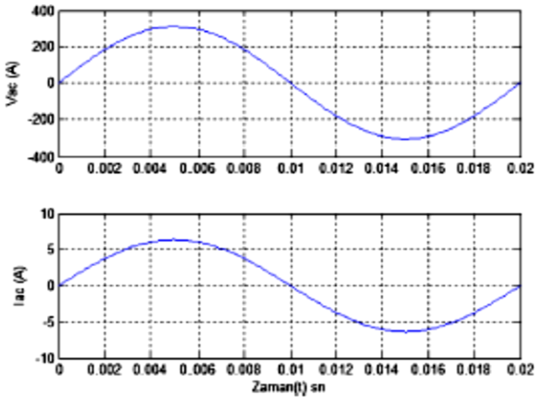

Figure 18. AC voltage and current of inverter

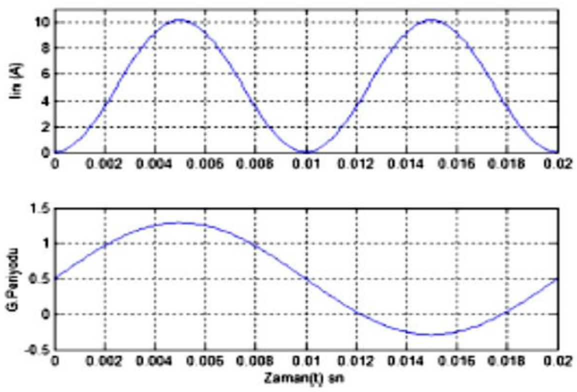

Figure 19. Solar PV module I-V curves under different module temperature values

In order to determine the appropriateness of the hybrid solar PV system, we are modelling a solar PV integrated utility grid using the MATLAB/Simulink programme. This will enable us to plan to determine the hybrid solar PV technique's applicability. In order to manage the DC voltage, a new organising strategy is used in this article. The features of the current-voltage and power-voltage curves for the solar PV idea, which have been evaluated with a range of solar input power levels, are shown in Figure 20. Figure 21 shows the solar PV system's output power as well as voltage.

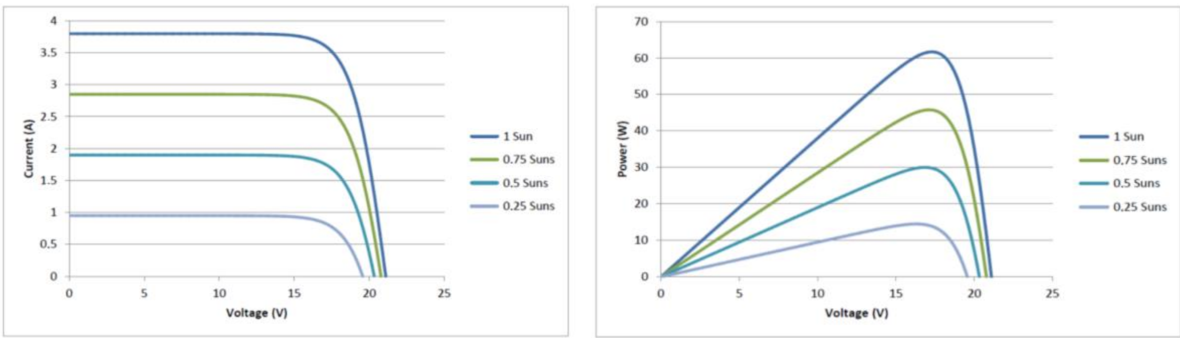

Figure 20. Solar PV generator model

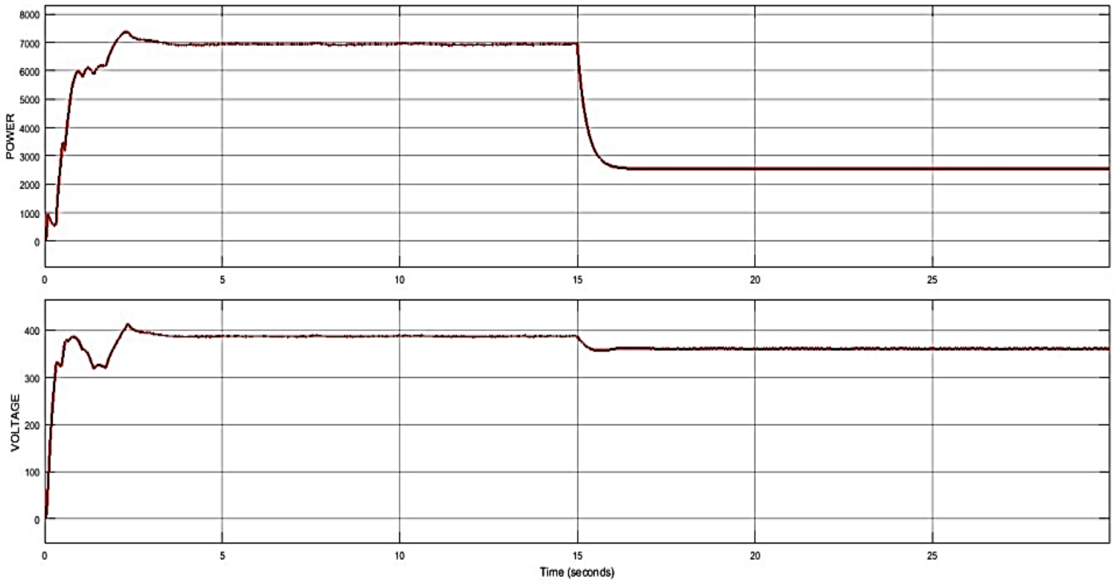

Figure 21. Output voltage and output power of solar PV method

4. CONCLUSION

This study examined a utility grid's control strategy for a hybrid energy production and control system. Because the environment of load demand is always changing and renewable power sources are also becoming more common, an energy system that combines solar PVs and SOFC is crucial. The establishment of a SOFC integrated solar PV hybrid energy production system using Simulink was discussed. The converter input is used in preference to the solar PV system's performance output. The solar PV system's output is also meant to serve as the inverter's energy input. The solar PV system is connected to the utility grid, and the deployment of fuel-cell systems might support the DC bus, which is a part of the integrated energy power generation system. All of the results that were discovered via the integration of two significant renewable energy systems should be discussed in the article. The analyse system is meant to be modular, making the development and modelling of grid interfaces for SOFCs and solar PV systems easier than flexible design. After being simulated, the hybrid system is then well-ordered and verified using a range of various control strategies in MATLAB/Simulink.

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BIOGRAPHIES OF AUTHORS

Manjunathan Alagarsamy received the engineer degree in Electronics and Comunication Engineering from Dr. Navalar Nedunchezhiyan College of Engineering in 2010. He received the master degree in Embedded System Technologies from Raja College of Engineering and Technology, Madurai, Tamilnadu, India in 2013. He is currently working as an assistant professor in the Department of Electronics and Communication Engineering at K. Ramakrishnan College of Technology, Trichy, India. His area of interests includes embedded systems, image processing, sensors and interfacing networks and IoT. He has published 33 articles in peer reviewed international journals and presented 7 papers in international conferences. He can be contacted at email: manjunathankrct@gmail.com.

Neera Chaudhary is an assistant professor in the Departement of Computer Engineering at New Horizon College of Engineering, Bangalore, India. She has recived the Engineering degree in the field of Computer Science and Engineering from Raj Kumar Goel Institute of Technology for Womens in 2017. She has received the master degree in Information Security from Ambedkar Institute of Advance Communication Technology and Research, New Delhi, India in 2019. She has received best paper award for one of her research paper. Her area of interest includes semantic web, IoT, and artificial intelligence. She has published 3 papers in international conferences and 3 papers in journals. She has also published 3 patents. She can be contacted at email: neerachaudhar18@gmail.com.

Nithyadevi Shanmugam received the Bachelor of Engineering degree from Sasurie College of Engineering, Vijayamanagalam in 2009, Master of Engineering from Anna University Regional center, Coimbatore 2013. She is pursuing Ph.D degree in Testing of Low power VLSI digital circuits from Anna University, Chennai. She is an assistant professor at Dr. N.G.P. Institute of Technology, Coimbatore since 2016 and earlier she had gained her experience from Info Institute of Technology, Coimbatore. She has totally 13 years of teaching experience. She has authored 8 research publications both international and national journals and presented 11 papers in international conferences. Her areas of interest include testing of VLSI digital circuits, artificial intelligence, signal processing and VLSI for wireless communications. She is a life member of professional bodies like ISTE, IETE, and IAENG. She can be contacted at email: ndsnithya88@gmail.com.

Kannadhasan Suriyan is working as an assistant professor in the Department of Electronics and Communication Engineering in Study World College of Engineering, Coimbatore, Tamilnadu, India. He is Completed the Ph.D in the field of smart antenna for Anna University in 2022. He is twelve years of teaching and research experience. He obtained his B.E in ECE from Sethu Institute of Technology, Kariapatti in 2009 and M.E in Communication Systems from Velammal College of Engineering and Technology, Madurai in 2013. He obtained his M.B.A in Human Resources Management from Tamilnadu Open University, Chennai. He has published around 45 papers in the reputed indexed international journals indexed by SCI, Scopus, Web of science, Major indexing and more than 146 papers presented/published in national, international journal and conferences. Besides he has contributed a book chapter also. He also serves as a board member, reviewer, speaker, session chair, advisory and technical committee of various colleges and conferences. He is also to attend the various workshop, seminar, conferences, faculty development programme, STTP and Online courses. His areas of interest are smart antennas, digital signal processing, wireless communication, wireless networks, embedded system, network security, optical communication, microwave antennas, electromagnetic compatability and interference, wireless sensor networks, digital image processing, satellite communication, cognitive radio design, and soft computing techniques. He is Member of SMIEEE, ISTE, IEI, IETE, CSI, IAENG, SEEE, IEAE, INSC, IARDO, ISRPM, IACSIT, ICSES, SPG, SDIWC, IJSPR, and EAI Community. He can be contacted at email: kannadhasan.ece@gmail.com.

Arulmurugan Loganathan is working as an associate professor in the Department of Electronics and Communication Engineering, Bannari Amman Institute of Technology, Sathyamangalam, Erode. He holds a Ph.D degree in the area of Information and Communication Engineering from Anna University. He has completed BE in Electronics and Communication Engineering from Bharathiar University and ME in Applied Electronics from Anna university, Chennai. His research interest is VLSI design, artificial intelligence, decision support system, phase change materials, and electronics cooling system. He can be contacted at email: arulmurugan83@gmail.com.

Raja Manikandan received the engineer degree in Electronics and Comunication Engineering and master degree in Communication Systems from Bharath Niketan Engineering College in 2010 and 2014. He is currently working as an assistant professor in the Department of Electronics and Communication Engineering at K. Ramakrishnan College of Technology, Trichy, India. His area of interests includes communication systems, image processing, sensors and interfacing networks, and internet of things. He can be contacted at email: mrajasiva@gmail.com.