Design of Grid-Connected Battery Storage Wave Energy and PV Hybrid Renewable Power Generation

S. Sunanda and M. Lakshmi Swarupa

1 Introduction

In close proximity to end customers, embedded generation (EG) produces energy on a modest scale (10 kW–10 MW) and is straightforwardly connected to the conveyance organization (DN). The entrance of EG affects how the appropriation framework (DS) works [1], regardless of whether the reconciliation of EG into DS is intended to offer dependability, reactive power compensation, loss reduction, and voltage support [2, 4]. The integration of EG has a significant influence on the operation of the grid [6], the voltage profile [7–9], the power quality [10, 11], the lattice misfortunes [12], the issue current level [13], and the ongoing security framework [14–18].

It may be deduced from the literature that researchers are primarily interested in how to safeguard distribution systems from failures by creating protective equipment including fuses, relays, surge diverters, surge arresters, circuit breakers, and hybrid protective systems [19–24]. To fill an unmistakable exploration hole recognized to relieve (settle) the adverse consequences on conveyance framework security with EG incorporation, this paper surveys the benefits of inserted age on the matrix [25] and examines how implanted age will present effects [26] on insurance of dissemination system [27].

Advantages of Embedded Generation to the Grid

- Decreased dispersion and transmission misfortunes. Contingent upon the area and execution during busy times, it may be possible to postpone network augmentation.
- Voltage support increased power system robustness.

S. Sunanda
St. Martins Engineering College (A), Dullapally, Secunderabad, India

M. Lakshmi Swarupa (✉)
CVR College of Engineering, Ibrahimpatnam, India
e-mail: swarupamalladi@cvr.ac.in

V. K. Gunjan et al. (eds.), *Computational Intelligence in Machine Learning*, Lecture Notes in Electrical Engineering 1106, https://doi.org/10.1007/978-981-99-7954-7_8

- Possibility of reducing emissions.

Pros of the Grid for Deployed Embedded Generation

- Empowers admittance to precursor markets
- Supports the safeguarding of unwavering quality for inconsistent inserted age
- Advances voltage quality, which is urgent for end-use gadgets
- Reinforces the functional adequacy of implanted creating since yield need not represent nearby burden
- Upholds the client's beginning up power needs when top current might climb recognizably.

Significant Effects of the Integrated Generation

The following difficulties, which are listed in [28, 29], are the key ones raised in this study about the entrance of implanted ages into current dispersion frameworks.

- Reverse energy flow
- Energy losses
- Coil voltage
- Operation islands battles
- Increasing fault current
- Power quality issues
- Stability
- The few performance index factors that need to be taken into account for analysis include safe penetration limits estimate, etc.

In this article, four important concerns from the previously mentioned challenges with EG integration have been taken into consideration for the distribution network analysis. estimate of the penetration level, reverse power flow, voltage profile, and fault current rise. in the event that DN and EG are combined. Identifying power flows in both directions is critical for DN protection in cases when local generation exceeds local demand. For this reason, reverse power relay [30] is used in this article; it will recognize the bearing where shortcoming emerges according to the place of hand-off and assist in finding a solution to circumstances when protection is compromised. Because of the overvoltage that results from EG penetrations into the DN, problems in these areas are more difficult to diagnose and repair, and EG integration is what ultimately causes the DN to transform from radial to bidirectional. Therefore, protection of the DN is required in terms of voltage profile and fault current reduction because to the higher fault current brought on by the contribution from EGs and further worsened during times of fault. When failures occur in power distribution systems, fault currents and over voltages are introduced that must be mitigated. This article is the first to examine the use of a superconducting fault current limiter (SFCL) for this purpose, and an active type SFCL is now commercially available [31, 32].

Additionally, SFCL is included to enhance communication amongst protective devices [33] and testify to its effectiveness. After conducting experimental studies [34] to decide what amount of time it requires for an issue to become obvious in a perplexing framework, leading tests [35] to determine how well SFCLs perform at different locations within the power system, and conducting cost-benefit analyses [36] of the power dissipation [37] factor during SFCL operation, the team arrives at the conclusion that multiple resistive SFCLs can be effectively applied. Practical application issues [38] are then recognized. Finally, SFCL [39]'s properties are also discussed. From the aforementioned literature, it was clear that there was a research gap that needed to be filled SFCL functioning as a passive resonance carrier-based (PRCB) Over voltage and a larger fault current may be mitigated by using SFCL and inverse current injection CB (I-CB) during fault periods. The following are the writers' contributions to this paper's goals.

- To distinguish between symmetrical and unsymmetrical errors that are severe, a test procedure has been built up.
- As determined by monitoring the fluctuations in active and reactive power, the least impacted EG among all linked EGs.
- By planning the settings for the reverse power relay, a technique is established to locate and isolate EGs at the time of problems.
- Modern methods: The use of SFCL as a passive resonance CB (PRCB) and inverse current injection (I-CB) CBs is recommended as a method for diminishing the enormous shortcoming flows and over voltages welcomed on by EG entrances and blames, separately.
- The recreation aftereffects of the two proposed techniques under extreme shortcoming (LLLG) with the most un-impacted EG (SOFCEG) were thought about, ideas were made for the plan of defensive gadgets (circuit breakers), and the penetration levels of various EGs were computed and analyzed using standard mathematical formulas.

2 Problem Formulation

The sort of EG unit is being used has a significant effect on planning and operational considerations such voltage profile, power quality, power misfortunes, dependability, and defensive framework. Direct connections to the distribution grid are possible for both synchronous and asynchronous generators, as well as other EG units. Power electronic converters are another option. The distribution grid's power flows and the aforementioned features are impacted in each scenario.

Types and Capacity of Embedded Generation

Different Embedded Generation Models: The two main categories of EGs are rotating machine EGs and inverter-based EGs. Since the produced voltage may take either a DC or AC form, inverters are often utilized in EG systems after the generating process. Because it must first be converted to DC before being transformed back into AC, it must be fine-tuned using the rectifier to the ostensible voltage and recurrence with the ostensible boundaries. According to their terminal properties in terms of their ability to generate real and reactive power [41], EG may be roughly categorized

Table 1 Major EG kinds depending on their capacity to produce power [42]

EG type	Type description	Example
Type 1	EG has the capacity to inject both reactive and actual power	Synchronous power plants
Type 2	While EG may inject actual power, it also consumes reactive power	Wind power farms, for example, use induction generators
Type 3	Only EG has the capacity to provide genuine power	PV, micro-turbines, and fuel cells integrated with converters and inverters into the main grid
Type 4	Only reactive power may be introduced via EG	Synchronous compensators

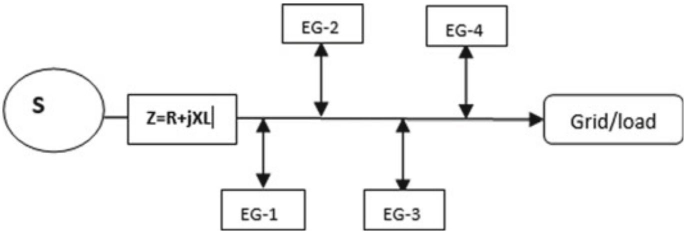


Fig. 1 Single-line schematic of a power system with integrated generation units

into four broad groups; several kinds of EG, as displayed in Table 1, have already been taken into account for this study.

Figure 1 illustrates how an EG is connected to a distribution network. This connection will undoubtedly cause some local alterations to the network's properties. Section 1 of this paper lists the primary difficulties. Of the issues presented, four have been taken into account for study and have pertinent remedies provided to secure the distribution system. A few of the difficulties include: assessment of penetration levels; voltage profile; invert power stream; expanded issue current; and reverse power flow.

2.1 Scenario 1: Rising Voltage Profile

The incorporation of EG into the DN will increase the voltage, which must be kept below legal limits for the DN to function properly (nearby voltage in addition to EG-based voltage should be not exactly the neighborhood interest).

2.2 Scenario 2: Backward Power Flow

Recommended in this present circumstance pivot power moves be acquainted with safeguard the dispersing framework against power inversions achieved by circumstance 1. In most cases, a radial distribution network will be set up such that power flows in just one direction, from the source down the distribution lines and into the loads. This assumption is reflected in the design of conventional protection systems, such as relays that trip in the event of an overcurrent. The load flow status might alter if there is an age on the dissemination feeder. The direction of the power flow will alter if local output is greater than local consumption.

2.3 Scenario 3: An Increase in the Fault Current's Size

At the point when EG is associated with a dissemination organization, the network's nearby point of connection experiences an increase in the fault current when there is a problem. When fault current values are surpassed, there is a potential that the DN may be damaged and fail, which increases the chance that people will be hurt and that supplies will be interrupted. For the system's protection equipment, the new shortcoming current and setting ought to be registered.

2.4 Scenario 4: The Traditional Method is to Estimate the EG's Penetration Limitations

To check the trial discoveries for the boundaries recently referenced, IEEE-14 base has been taken into account with four EGs (PVCELLS, MICRO TURBINE, SOFC FUEL CELL, and WIND TURBINE) in each example at picked transport no entrance levels. Distribution network characteristics have also been examined.

3 Proposed Solutions

Comprehensive hybrid system simulation in Simulink with lattice associated VSI is shown. The arranged cross breed framework comprises five significant parts: a photovoltaic exhibit, an on-board charger (OWC), a battery bank, a voltage source inverter, and a buck-help converter (BBDC) on the pile side with a relative fundamental (PI) control commitment cycle. A PV group, DC converter, and MPPT combined calculation comprises a sunlight-based PV framework. The OWC framework was constructed utilizing a bidirectional turbine controlled by a simultaneous generator (SG) and an air conditioner DC three-stage rectifier. Regularly, an inexhaustible PV

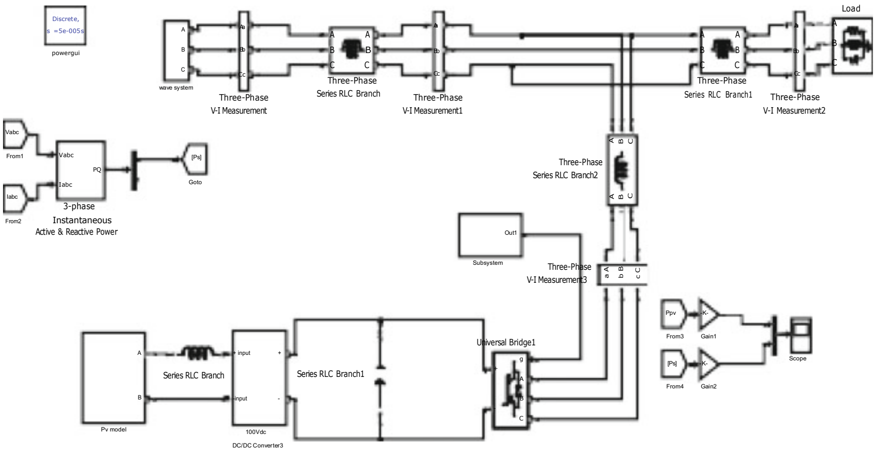


Fig. 2 Simulation model of hybrid system

and wave energy system will be the main power producing source in an HRES, while a battery bank will go about as a reinforcement energy capacity system to meet the system's load needs in the event of a power outage. In a hybrid setup, the PV, wave, and battery bank must all be connected by a DC link with a stable voltage. Thusly, the HRES utilizes a BBDC with a PI controller to keep the DC-interface voltage stable. A three-stage voltage source inverter (VSI) is used at the stack side to control the voltage's plentifulness and recurrence (Figs. 2, 3 and 4).

Parameters of ocean wave chamber [5]

OWC chamber length (L_{ch})	1.5 m		
Water surface area inside the chamber (A_1)	1.4 m^2		
Turbine inlet area (A_2)	0.012 m^2		
Water depth (d)	WH (m)	WP (s)	d (m)
	0.98	4.9	16.47
	0.9	4.79	15.75
	0.88	4.79	15.73

Parameters of PV array [5]

Maximum rated power (P_{max})	87 W
Maximum voltage (V_{max})	17.4 V
Maximum current (I_{max})	5.02 A
Open circuit voltage (V_{oc})	21.7 V
Short circuit voltage (I_{sc})	5.34 A

(continued)

(continued)

Maximum rated power ($P_{\max}$)	87 W
Number of module required	5

Simulation Results of Ocean Wave Chamber

See Figs. 5, 6, 7 and 8.

PV System Modeling Results

See Figs. 9, 10, 11, 12 and 13.

A Study of Hybrid-Grid System Simulation Results

See Figs. 14, 15, and 16.

Subsystem of SOFC System

See Figs. 17, 18 and Table 2.

Conclusions: Most of sustainable power sources are erratic and heavily depend on climatic conditions, making it difficult to build a hybrid renewable power producing system. To meet the high energy demands in this challenging environment, researchers have been working on a mixture power creating framework that coordinates matrix associated battery capacity with PV, wave, and SOFC renewable energy sources, all controlled by an efficient power management algorithm. Maximum power output voltage of 650 V is exactly the same as the system's reference voltage, and therefore, it is clear that the system can operate properly at this voltage.

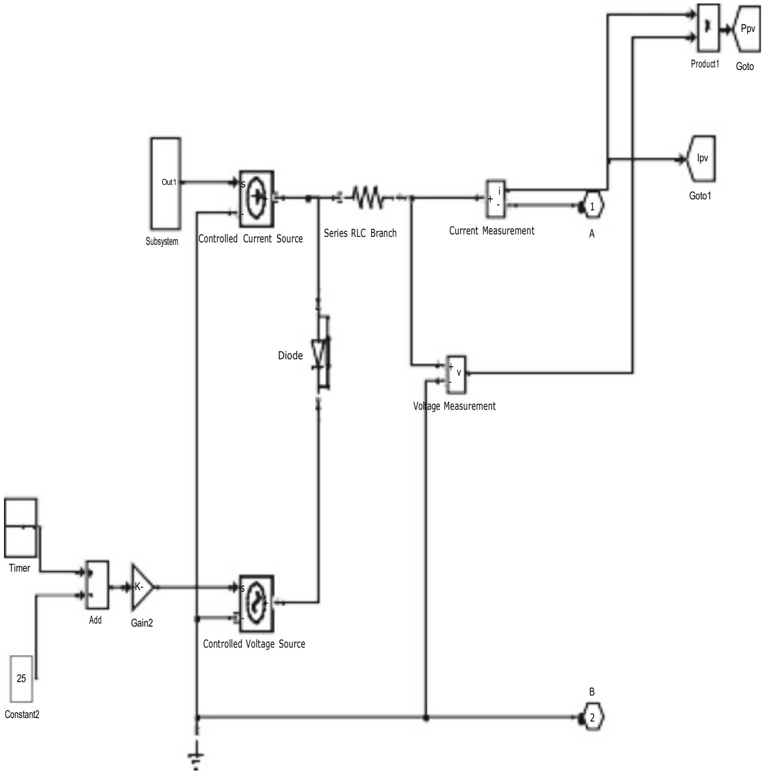


Fig. 3 Subsystem of solar PV

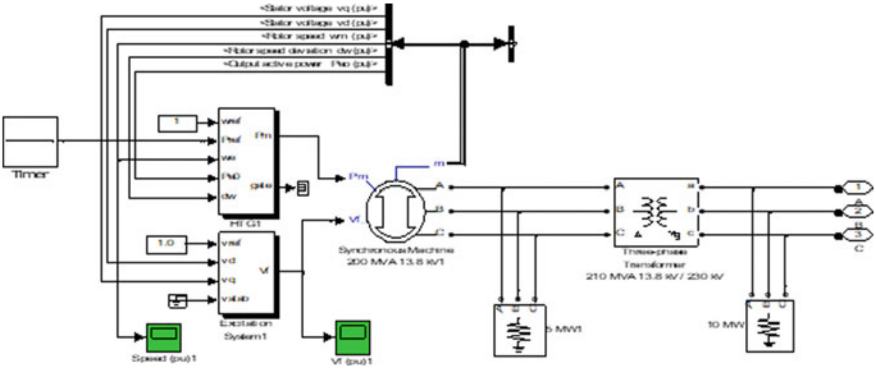


Fig. 4 Subsystem of ocean wave

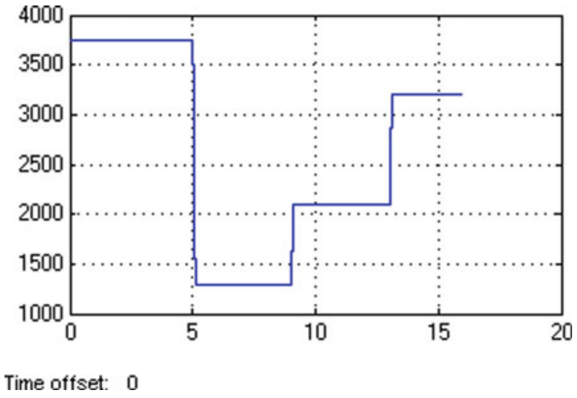


Fig. 5 Air velocity power of chamber P_a

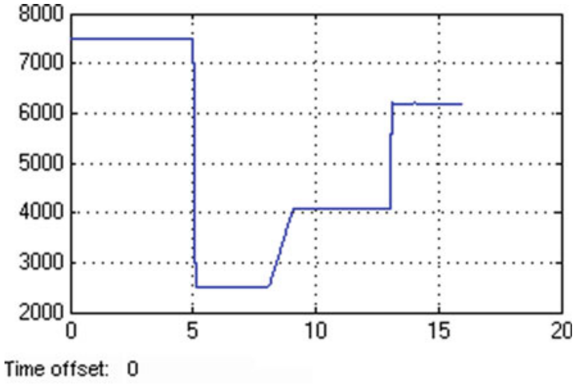


Fig. 6 Chamber pressure power P_p

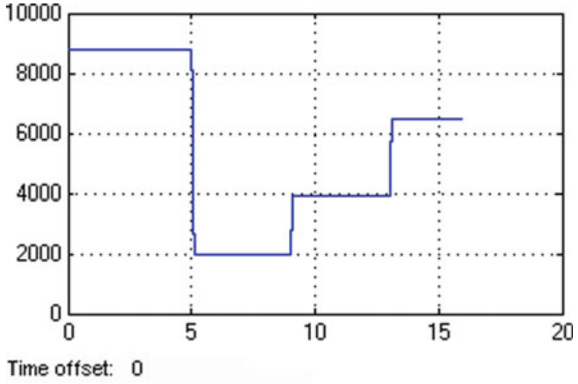


Fig. 7 Total power of chamber P_{ch}

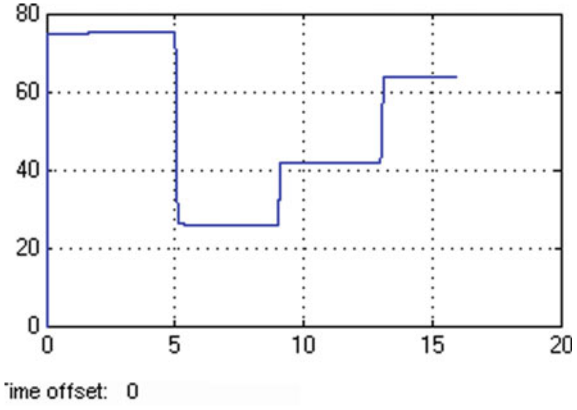


Fig. 8 Total power (P_w) generated by OWC system

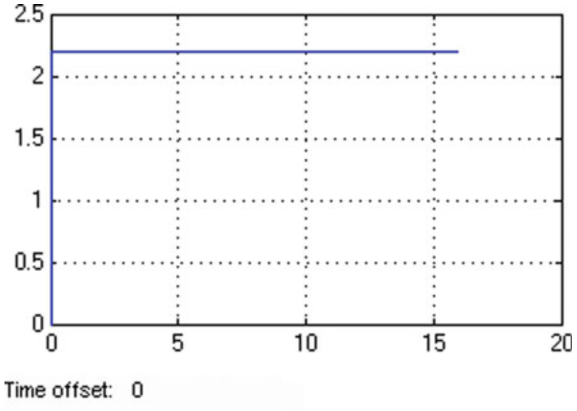


Fig. 9 Total output current (I_{pv}) of PV array

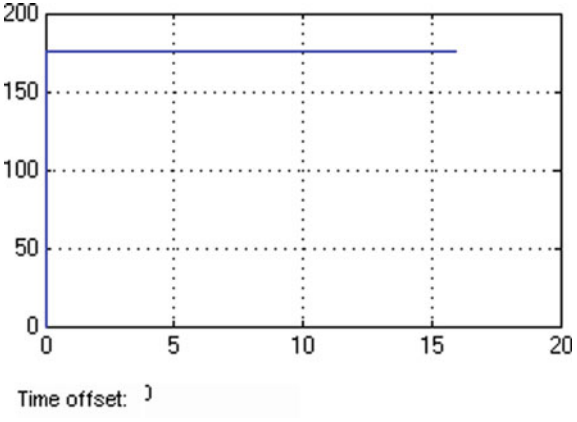


Fig. 10 Total output voltage (V_{pv}) of PV array

Fig. 11 Total output power P_{pv} of PV array

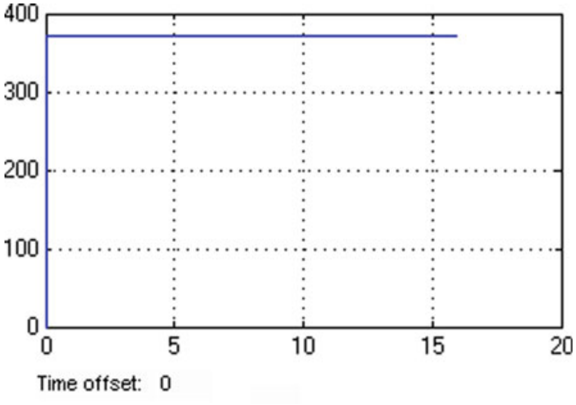


Fig. 12 Total DC link voltage

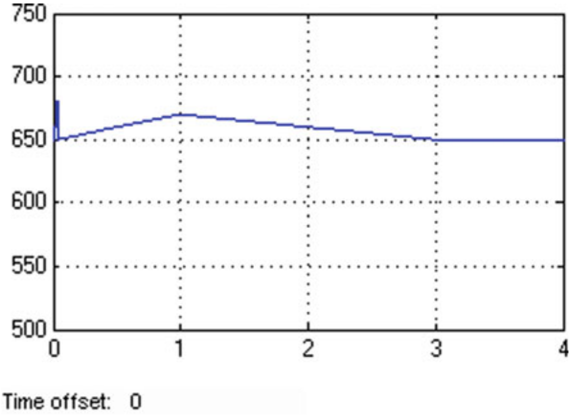


Fig. 13 Battery voltage

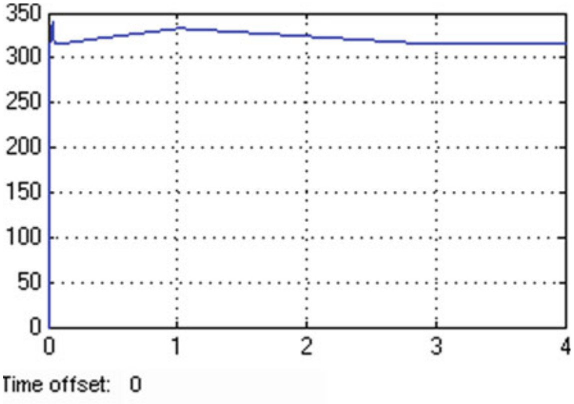


Fig. 14 Three-phase grid voltage versus time (s)

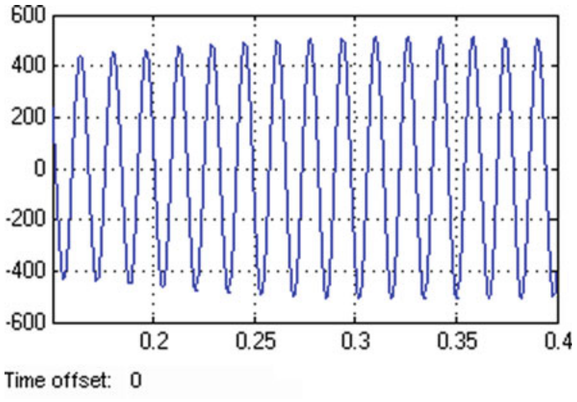
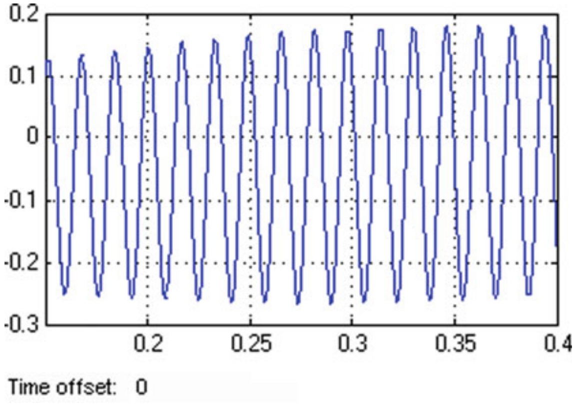


Fig. 15 Three-phase grid current versus time (s)



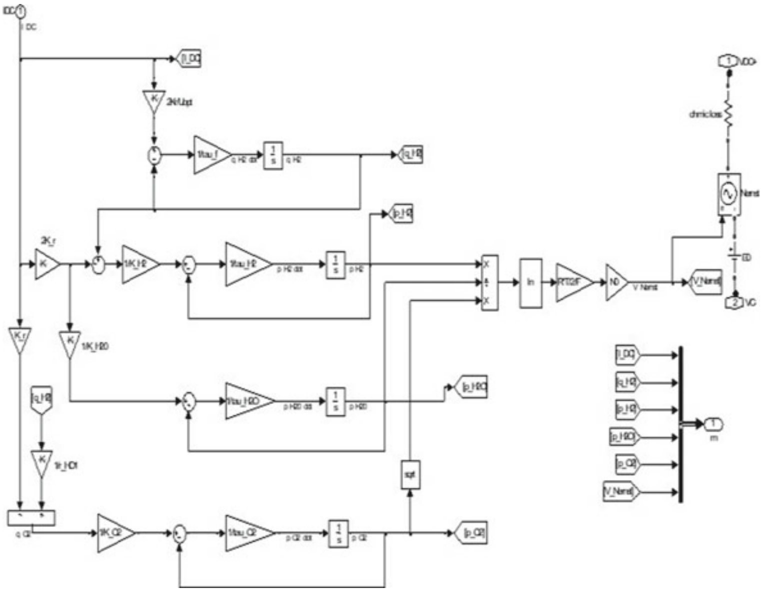


Fig. 16 Simulation results of SOFC system

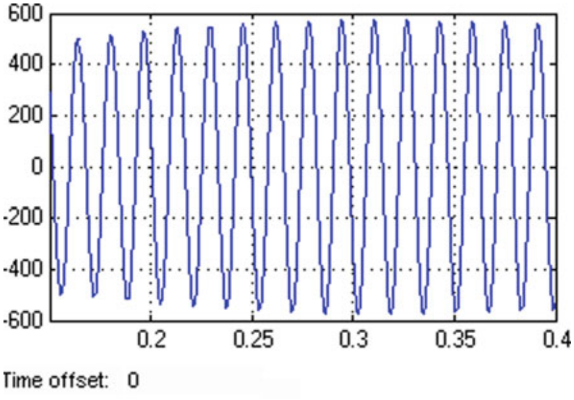


Fig. 17 Three-phase grid voltage versus time (s)

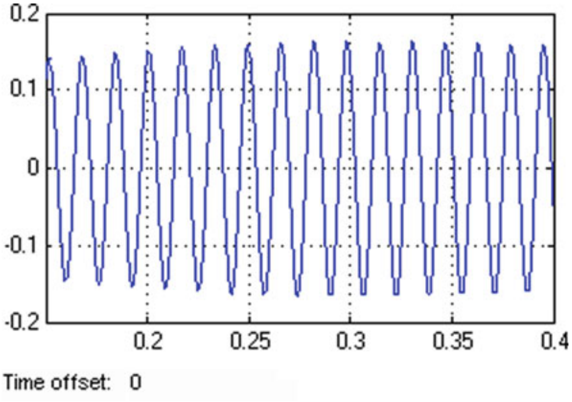


Fig. 18 Three-phase grid voltage versus time (s)

Table 2 Comparison table

	Generating	
	Voltage (V)	Current (A)
Ocean wave system	410	0.18
Solar PV system	450	0.19
SOFC system	510	0.22
Hybrid system	650	0.21

References

1. Podder S, Khan RS, Alam Mohon SMA (2015) The technical and economic study of solar-wind hybrid energy system in coastal area of Chittagong, Bangladesh. J Renew Energy 2015:1–10
2. Baek S, Kim H, Chang H (2015) Optimal hybrid renewable power system for an emerging island of South Korea: the case of Yeongjong island. Sustainability 7(10):13985–14001
3. Ahmad S, Albatsh FM, Mekhilef S, Mokhlis H (2014) A placement method of fuzzy based unified power flow controller to enhance voltage stability margin. In: Power electronics and applications (EPE'14-ECCE Europe), Aug 2014, pp 1–10
4. Mahamudul H, Silakhori M, Henk Metselaar I, Ahmad S, Mekhilef S (2014) Development of a temperature regulated photovoltaic module using phase change material for Malaysian weather condition. Optoelectron Adv Mater Rapid Commun 8(11–12):1243–1245
5. Samrat NH, Ahmad NB, Choudhury IA, Taha ZB (2014) Modeling, control, and simulation of battery storage photovoltaic wave energy hybrid renewable power generation systems for island electrification in Malaysia. Sci World J 2014:1–21
6. Ozaki Y, Miyatake M, Iwaki D (2010) Power control of a stand-alone photovoltaic/wind/ energy storage hybrid generation system with maximum power point tracker. In: International conference of electrical machines and systems (ICEMS), Nov 2010
7. Jian C, Yanbo C, Lihua Z (2011) Design and research of off-grid wind solar hybrid power generation systems. Power Electron Syst Appl
8. Lund H (2006) Large-scale integration of optimal combinations of PV, wind and wave power into the electricity supply. Renew Energy 31(4):503–515
9. Rehman S, Mahbub Alam M, Meyer JP, Al-Hadhrami LM (2012) Feasibility study of a wind–PV–diesel hybrid power system for a village. Renew Energy 38(1):258–268
10. Bhende CN, Mishra S, Malla SG (2011) Permanent magnet synchronous generator-based Standalone wind energy supply system. IEEE Trans Sustain Energy 2(4):361–373