Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 11, November -2017

DYNAMIC STABILITY ENHANCEMENT OF HYBRID SYSTEM USING FUZZY LOGIC CONTROLLER

B.Sandya[1], Dr S.Suresh Reddy[2], K.V.Thulasi Ram[3], M.Sankaraiah[4]

[1]M.Tech student, NBKRIST,Vidyanagar, SPSR Nellore, AP, India-524413
[2]Prof&Head, NBKRIST,Vidyanagar, SPSR Nellore, AP, India-524413
[3&4]Asst.Prof, NBKRIST,Vidyanagar, SPSR Nellore, AP, India-524413

Abstract:*This paper proposes discrete dynamics which plays a major role in the long term stability analysis, incorporates the model of wave speed with different probability distributions. In this paper mainly concentrated on generating pulses by using Pulse Width Modulation(PWM) methodologies for Fuel Cell(FC) application. The two phase supply of Boost converter proposed with voltage multiplier cell power system application. PWM controller performed by combining Alternative Phase Shift(APS) and conventional PWS controller. The single Fuzzy Logic Controller(FLC) is utilized for damping the oscillations in the FC voltage and the FC current. The APS is preferred to reduce the voltage unbalance on the switches and also maintained virtual reliability at over load conditions. The executed algorithm which can balance effectively by the APS controller. This paper proposes FLC scheme to maintain stable operation of the system while achieving maximum power extraction from the wave and photovoltaic (PV) systems.*

Key words : *Distributionpowergrid,dynamicstability,linear permanent-magnet generator, photovoltaic array, Fuel Cell, fuzzy logic controller,super-capacitor,time-domainsimulations.*

I. Introduction

Various topics related to the HPGS shavebeenextensivelyre-portedinliterature[2],[6]–[16].Theauthorsin[2]presented the dynamic modeling and control of aproposed grid-connected PV- wind-batteryHPGSwithversatilepowertransferwhichenabled the multi-modes of operation of the proposed system. In [6], a HPGS combining wind, PV, FC, electrolyzer, and battery was proposed for the stand-alone applications while a power managementstrategywasdesignedforthesystemtocoordinatethe powerflowsamongthedifferentenergysources.Severalpower management strategies of the grid-connected HPGSs were proposed in [7]–[9].

A design optimization of an autonomous wind-PV-batteryHPGSwasillustratedin[10]whereasadesign optimization technique for a grid-connected wind-PV-battery HPGS based on a multi-objective genetic algorithm was re-portedin[11].Dynamic stability of amicrogrid connecting with a wind turbine generator, a diesel synchronous generator, and a battery-based energy storage system was investigated in [12] while the small-signal stability improvement results of a grid-connected PV-diesel engine HPGS using an auxiliary signal in PVcontrolloopwerepresentedin[13].Theauthorsin[14]pro-posedanovelcontrolschemebasedonthestateofchargeofthebatterytoimprovetheperformanceofawind-PV-battery-based HPGS.TheapplicationofaSMEStoenhancedynamicsecurity of a grid-connected wind-PV HPGS during grid voltage sag was investigated in [15] while the voltage stabilization of a hybrid micro-sgrid using SCs was reported in[16].ItshouldbenotedthatmostoftheproposedHPGSsreported in literature were mainly based on wind and PV. This is due to thefactthatwindandPVcancomplementeachotherandtheir technologies have been well-established. Nevertheless, ocean energywhichisanabundantRESShasbeensteadilydeveloping towards pre-commercial and commercial operation in recent years[17].

Thisislikelythattheoceanenergywillcontributea significant portion to the electricity generation portfolio in the very near future. Among the available forms of ocean energy such as wave, marine current, tidal, ocean thermal, etc., wave energyisoneofthemostinterestingandpromisingsourcesfor electricity generation due to its features of high power density and widespread availability[18]–[21].Although a great deal of excellent research on the topics of wavepower-generationsystems(WPGSs)hasbeenundertaken and reported [17]–[20], the combination of the WPGSswith other RESs in the HPGSs has not been widely studied. Only a few published papers such as [3]–[6] have reported about the HPGSs including the wave power. The integration of wind and wave power generation systems using a dc micro-grid was studiedandreportedin[30]whileacombinationoffourdifferentwaveenergyconversiondevicesconnectedtoadistribution substation. The authors in [18] had developed a standalone PV-wave hybrid renewable power generation system for implementing in island areas in Malaysia. In that hybrid scheme, the WPGS was simulated by a PMSG driven by an oscillating water column device and the battery bankwasusedasabackupenergy-storagesystem.

In this paper, the dynamic stability enhancement results of a grid-connected wave and PV HPGS with the help of a SC for smoothing out the fluctuations are present. A control scheme is proposed to smoothen the power fed to the grid and maintain stable operation while extracting maximum power from both wave and PV renewable resources. Theperformanceofthestudiedsystemandtheeffectivenessof the SC combined with the proposed control scheme are examined through both the fuzzy logic controller and the time-domain simulationresults.

This paper is established as given. The configuration and employed models of the studied system are presented in section II. The control scheme for the studied system is discussed in section III. The fuzzy logic control and the time domain simulation results of the system are observed in section IV and V, respectively. Final conclusion of this paper in section VI.

II. SYSTEM STRUCTURE AND MATHEMATICAL MODELS

A. Structure of the studied system

Fig. 1 Shows the structure of the studied hybrid wave and PV system connected to a distribution power grid. The PV system and wave power-generation system (WPGS) are combined to a common DC link through a dc/dc boost converter and an ac/dc voltage-source inverter(VSI). The dc/dc boost converter connecting the PV array to the common dc link has maximum power point tracking (MPPT) function to make it operate as an MPPT controller. The WPGS comprise of a linear permanent-magnet generator(LPMG) driven by Archimedes wave swing(AWS).

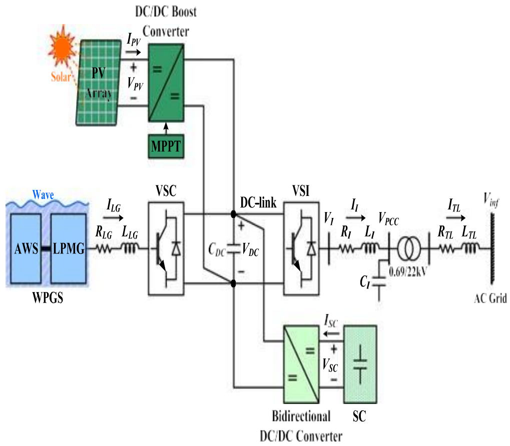


Fig. 1. Configuration of the studied hybrid wave and PV system integrated into a distribution powergrid.

As for the power afford to the dc link from the WPGS and the PV array are fluctuated, an energy storage device can be used to support for smoothing these power fluctuations. Mostly, batteries have been used with the renewable power generation systems due to their advantages in terms of low capital cost, high energy density and mature technology. In the same way batteries have some drawbacks such as slow response time, limited number of cycles and short life span which makes them less desirable for compensating the fast power fluctuation, mainly the ones with high value of peak to a average power ratio provided by the WPGS and high frequency power fluctuations of the PV array, the engaged energy storage evice should have the characteristics of high power density and fast response time during charging and discharging stages. In addition, the engaged energy storage device is also required to have large number of cycles, long life span, high efficiency, and low maintenance cost. The emerging energy storage technologies such as super capacitor (SC)and superconducting magnetic energy storage(SMES)can be the good can did ates for satisfying the aforementioned requirement. The SC and the SMES could compete with each other sincetheyhavesimilar merits in terms of high power density, fast response time, and long service life. Therefore, the SCisadaptedforsmoothingthepowerfluctuationsofthestudiedhybridwaveand PV power generation system in this paper. The SCisalsoconnectedtothedclinkthroughabidirectionaldc/dcconverter.To smooth the power fluctuations and maintain stable operation of the studied system while achieving the maximum power extractions from the renewable-energy sources, the control functions of the converters and the inverter must be properly performed. The control scheme for the studied system will be discussed in the next section. The engaged mathematical models foreachsub system shown in Fig.1aredescribedhereafter.

B. Framework of AWS-based WPGS

The framework of the AWS-based WPGS explains the mechanical dynamics of the AWS and the electrical dynamics of the LPMG. As the floater of the AWS is directly coupled with the translator of the LPMG, they can be utilized as a single mass. The mass spring damper system can be used to model the dynamics of the AWS. Thus, the mechanical dynamics of the AWS can be explained by the motion of equations as follows;

$$p(z) = u_z \quad (1)$$

$$(m_t)p(U_z) = F_{wave} - k_s z - K_D U_z - F_{Ltt} \quad (2)$$

Where p is the differential operator with respect to time t (p=d/dt); z and U_z are the distance and speed of the floater, respectively; m_t is the total mss of the floater and the LPMG translator; F_{WAVE} is the driving force acting on the floater from the waves, F_{LG} is the force acting on the floater from the LPMG; and K_D and K_S are the damping coefficient and spring constant of the AWS, respectively.

The LPMG's model based on *dq*-axis reference frame fixed in the translator can be written by [6],[8]:

$$(L_{dLtt})p(i_{dLtt}) = \omega_z L_{qLG} i_{qLG} - R_{LG} i_{dLG} - v_{dLG} \quad (3)$$

$$(L_{qLG})p(i_{qLG}) = \omega_z \psi_{PM} - \omega_z L_{dLG} i_{dLG} - R_{LG} i_{dLG} - v_{qLG} \quad (4)$$

where i_{dLG} and i_{qLG} (v_{dLG} and v_{qLG}) are the *d*- and *q*-axis currents (voltages), respectively; R_{LG} is the stator-winding resistance, L_{dLG} and L_{qLG} are the *d*- and *q*-axis synchronous inductances, respectively; ψ_{PM} is the flux linkage of the permanent magnet; and

$\omega_z = \pi U_z / \tau_p$ (τ_p is the pole pitch of the LPMG).

C. Framework of PV Array and dc/dc Boost Converter

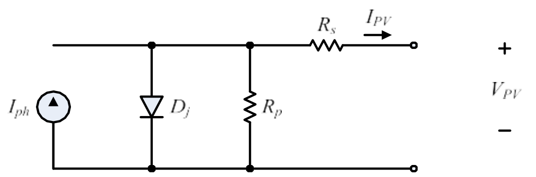


Fig. 2. Single-diode equivalent-circuit model of a PV cell.

The PV array is consists of several PV modules inter linked in series/parallel. Each PV module is constituted by a number of PV cells connected in series Fig.2 shows the single-diode equivalent -circuit of a PV cell which consists of a current source I_{ph}, a diode D_j, a parallel resistance R_p and a series resistance R_s .

$$I_{pv} = N_{mp} I_{ph} - N_{mp} I_0 \left\{ \exp\left[\frac{q(V_{pv} + R_{sa} I_{pv})}{kAT N_s N_{ms}} \right] - 1 \right\}$$
$$-(V_{pv} + R_{sa} I_{pv}) / R_{pa} \quad (5)$$

where V_{pv} is the output voltage (in V) of the PV array; N_{mp} are the numbers of PV modules connected in series-connected cells in a PV module; R_{sa} and R_{pa} are the equivalent series and parallel resistance (in Ohms) of the PV array, respectively; and I_{ph} and I_0 are the photovoltaic and reverse saturation currents(in A), respectively.

The current I_{ph} and I_0 are shown as follows [14],[15];

$$I_{ph} = [I_{sc,n} + k_i (T - T_n)](G / G_n) \quad (6)$$

$$I_0 = I_{0,n} (T / T_n)^3 \exp[(q E_g / kA)(1/T_n) - 1/T] \quad (7)$$

in which

$$I_{0,n} = I_{sc,n} / \{\exp[(q V_{oc,n}) / (kA T_n N_s)] - 1\} \quad (8)$$

Where T and G are the operating temperature (in K) and solar irradiance (in W/ m^2 , respectively; $I_{sc,n}$ and V_{oc} are the short- circuit current (in A) and open-circuit voltage (in V) in the standard test condition of T_n = 298.15 K (25 degrees) and G_n = 1000 W/m.m; I0,n is the reverse saturation current at T_n ; k_i is the short-circuit current coefficient (in eV); q,k and A are the electron's charge (in C), Boltzmann constant (in J/K) and diode ideally factor, respectively.ss

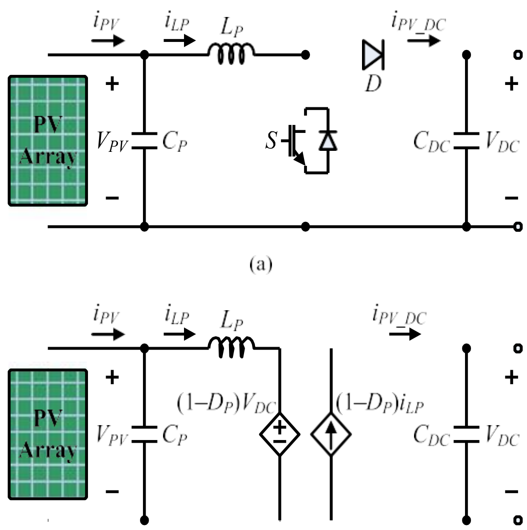
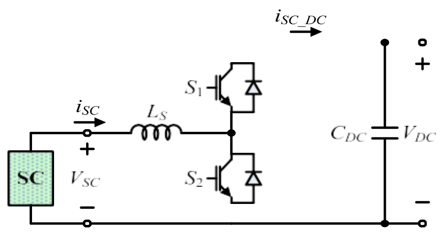


Fig.3 Schematic diagram and dynamic model of boost converter.

Fig. 3(a) plots the schematic diagram of the studied dc/dc boost converter for connecting the PV array to the dc link. Assumethatthedetailedswitchingactionsoftheswitch*S*andthe diode*D*showninFig.3(a)areneglected.Thedc/dcboostconverter can be represented by the dynamic average-value model asshowninFig.3(b).Thus,thedynamicequationsusedtosimulate the dc/dc boost converter can be taken by [16];

$$(C_p)p(V_{pv}) = i_{pv} - i_{LP}$$

$$(L_p)p(i_{pv}) = -R_p i_{LP} + V_{PV} - (1-D_P)V_{DC} \qquad (9)$$



$$i_{PV\_DC} = (1-D_P)i_{LP} \qquad (10)$$

Where C_p is the capacitance of the input filter; L_p and R_p are the inductance and parasite resistance of the energy-storage inductor of the converter, respectively; i_{LP} is the inductor current ; i_{PV_DC} is the current fed to the DC-link from the boost converter, V_{DC} is the DC-link voltage; and D_p is the duty ratio of the DC/DC boost converter.

D. Framework of SC and dc/dc Bidirectional Converter

Fig.4. explains the equivalent circuit framework of the studied SC. Based on Fig.4 the corresponding dynamic equations of the analysed SC can be obtained as

$$(C_{SC})P(V_{CSC}) = -i_{sc} - V_{csc}/R_{pSC} \qquad (11)$$

$$V_{sc} = V_{csc} - R_{sSC}/i_{SC} \qquad (12)$$

where V_{sc} and i_{sc} are the voltage and current of the SC, respectively; and V_{csc} is the voltage across C_{sc} . Fig. 5.2 shows the schematic diagram of the implement bidirectional DC/DC converter for interfacing the SC to the DC link.

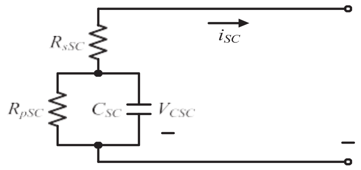


Fig. 4. Equivalent-circuit model of the SC

The low-voltage side of the bidirectional dc/dc converter is connected to the SC while its high-voltage side is tied to the dc link. The converter consists of an energy-storage inductor *LS* and two switches *S*1 and *S*2 which are operated in a complementary manner. This configuration

Fig.5 Schematic diagram and dynamic average value model of bi directional DC/DC converter.

enables the feature of the bidirectional power flow of the converter. In buck mode of operation, the switch *S*1 acts as a switch and *S*2 acts as a diode [20], and the power flows from the dc link to the SC.

E. Framework of Voltage-Source Inverter

The VSI, as shown in Fig.1, is connected to the distribution power grid through an *LC* filter, a step-up transformer, and a connection line. The dynamic models of these components under *dq*-axis reference frame can be writtenas:

$$(L_I)p(i_{dI}) = R_I i_{dI} = -R_I i_{dI} + \omega_e L_I i_{qI} + v_{dI} - v_{dPCC} \quad (13)$$

$$(L_I)p(i_{qI}) = -R_I i_{qI} - \omega_e L_I i_{dI} + v_{qI} - v_{qPCC} \quad (14)$$

$$(C_I)p(v_{dPCC}) = i_{dI} - i_{dTL} + \omega_e C_I v_{qPCC} \quad (15)$$

$$(C_I)p(v_{qPCC}) = i_{qI} - i_{qTL} - \omega_e C_I v_{dPCC} \quad (16)$$

Where (v_{dI} and v_{qI}) and (i_{dI} and i_{qI}) are the output voltages and currents of the VSI; (v_{dPCC} and v_{qPCC}) and ($v_{d\_\inf}$ and $v_{q\_\inf}$) are the voltages of the point of common coupling (PCC) and the distribution power grid, respectively; (i_{dTL} and i_{qTL}) are the currents of the connection line; and ω_e angular frequency (in rad/s).

III. CONTROL STRATEGY

The control strategy of the studied system is discussed in this section. This paper concentrated on the generating pulses by using pulse width modulation methodologies for fuel cell applications. The two phase interleaved boost converter proposed with voltage multiplier cell power system applications. PWM controller performed with the combination of alternating phase shift control and conventional PWM controller.The alternating phase shift control (APS) is utilized to compensate the voltage unbalanced on the switches and also maintained effective reliability when over loaded conditions. The middle level approach among the APS and interleaving technology which is utilized better performance. In this work single Fuzzy logic controller is proposed instead of two conventional controllers, which were used in the existing system.

The executed algorithm which can compensate the harmonics and voltage stress problems effectively by the APS controller. Finally the simulated framework is tested and verified within the MATLAB/SIMULINK with breakdown conditions.

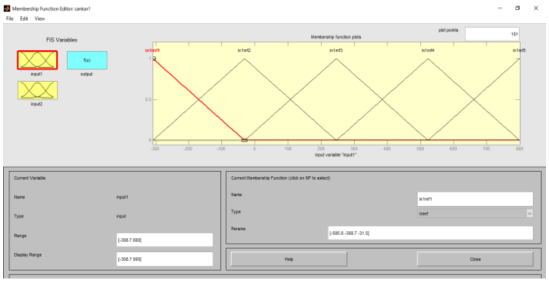


Fig.6. Input 1 membership functions of pr opposed controller

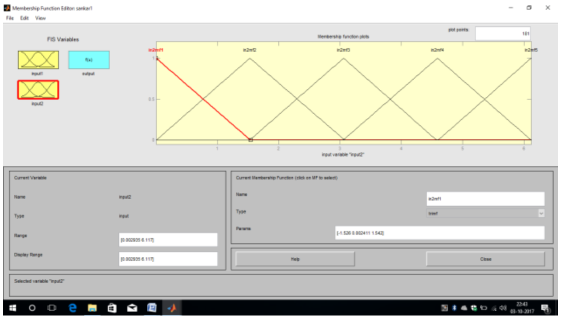


Fig .7. input 2 membership functions of proposed controller

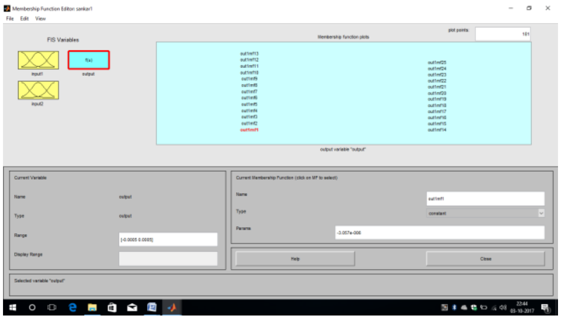


Fig .8. output membership functions of proposed controller

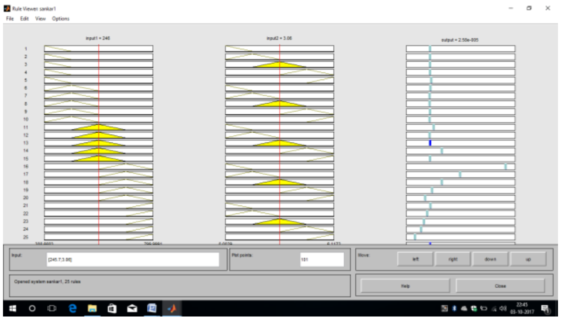


Fig.9.rules of proposed controller

IV TIME-DOMAINSIMULATIONS

A. Case 1: Variations ofWave Force

thesolar irradianceisassumedtobeconstantat200W/m^2.Initially,the peakamplitudeandtheperiodofthewaveforceare0.7MNand 12s,respectively.Thereafter,thepeakamplitudeofwaveforce drops to 0.4 MN at t = 40 s and steeply increases to 0.9 MNat t = 80s.

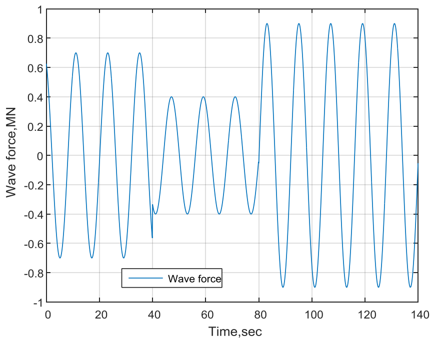


Fig.10 Wave Force

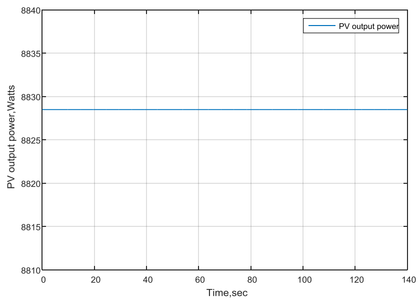


Fig.11 Solar Output

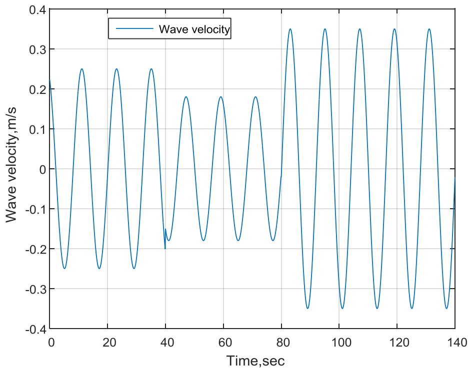


Fig.12 Wave Velocity

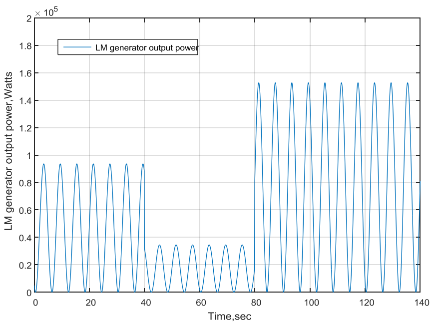


Fig.13 Power of LG

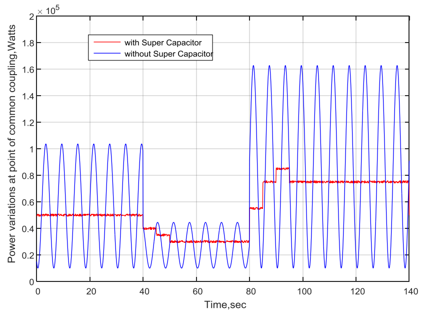


Fig.14 PCC Power

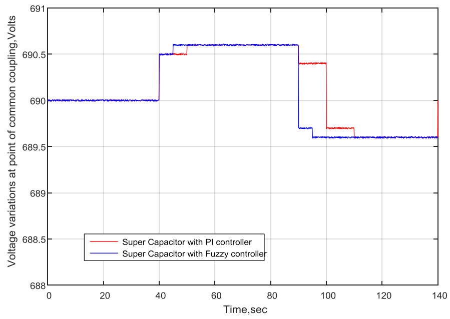


Fig.15 PCC Voltage

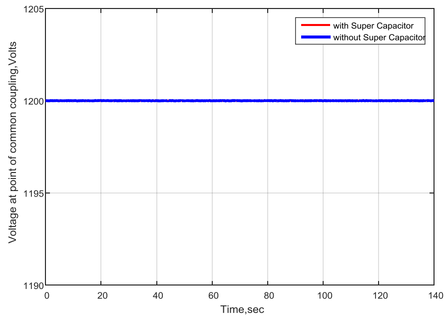


Fig.16DC link Voltage

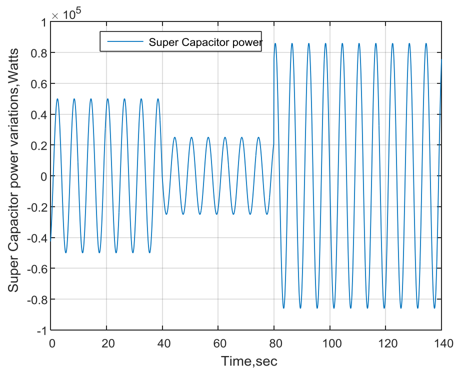


Fig.16 SC power

B. Case 2: Variations of SolarIrradiance

Wave force is kept at the peak amplitude of 0.2MN and the period of 12s. The solar irradiance is assumed to be increased from the initial value of 200 W/m^2 to the maximum level of 1000 W/m^2 at t=50sandgraduallyreducebackto200W/m^{2}at$t$=200s.

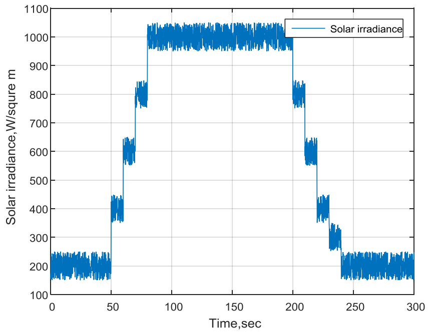


Fig.17 Solar Irradiance

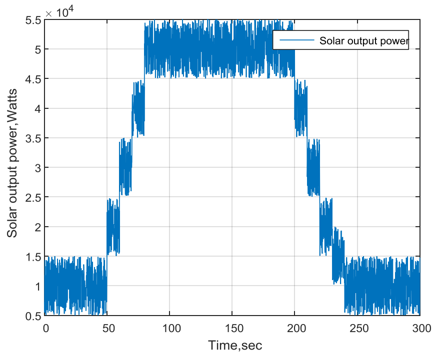


Fig.18 Solar power

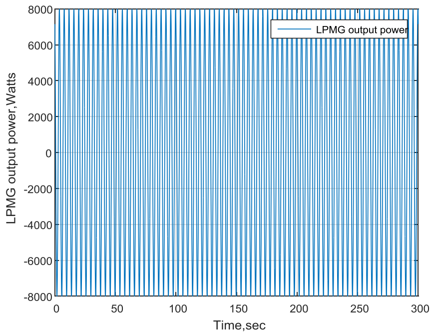


Fig.19 LG power

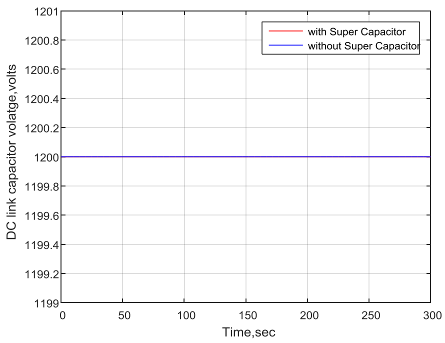


Fig.20 DC voltage

V. CONCLUSION

The stability of hybrid power system is enhanced by the proposed controller. The effectiveness of the proposed controller tested under solar power deviations and linear generator power deviations.

REFERENCES

[1]. C. Wang and M. H. Nehrir, "Power management of a stand-alone wind/photovoltaic/fuel cell energy system," *IEEE Trans. Energy Convers.*,vol. 23, no. 3, pp. 957–967, Sep. 2008.
[2]. M. Sandhu and T. Thakur, "Issues, challenges, causes, impacts and utilization of renewable energy sources—Grid integration," *Int. J. Eng. Res.Appl.*, vol. 4, no. 3, pp. 636–643, Mar. 2014.
[3]. S.-K. Kim, J.-H. Jeon, C.-H. Cho, J.-B. Ahn, and S.-H. Kwon, "Dynamicmodeling and control of a grid-connected hybrid generation system with versatile power transfer," *IEEE Trans. Ind. Electron.*, vol. 55, no. 4,pp. 1677–1688, Apr. 2008.
[4]. Y. J. Reddy, Y. V. P. Kumar, K. P. Raju, and A. Ramsesh, "Retrofittedhybrid power system design with renewable energy sources for buildings," *IEEE Trans. Smart Grid*, vol. 3, no. 4, pp. 2174–2187, Dec. 2012.
[5]. X. Li, D. Hui, and X. Lai, "Battery energy storage station (BESS)-basedsmoothing control of photovoltaic (PV) and wind power generation fluctuations," *IEEE Trans. Sustain. Energy*, vol. 4, no. 2, pp. 464–473,Apr. 2013.
[6]. M. I. Marei, M. Mokhtar, and A. A. El-Sattar, "MPPT strategy based onspeed control forAWS-basedwave energy conversion system," *Renewable Energy*, vol. 83, pp. 305–317, Nov. 2015.
[7]. A. J. Garrido, I. Garrido, M. Amundarain, M. Alberdi, and M. D. la Sen,"Sliding-mode control of wave power generation plants," *IEEE Trans. Ind. Appl.*, vol. 48, no. 6, pp. 2372–2381, Nov./Dec. 2012.
[8]. F. Wu, X.-P. Zhang, P. Ju, and M. J. H. Sterling, "Optimal control forAWS-based wave energy conversion system," *IEEE Trans. Power Syst.*, vol. 24, no. 4, pp. 1747–1755, Sep. 2009.
[9]. L. Cappelli*et al.*, "Linear tubular permanent-magnet generators for theinertial sea wave energy converter," *IEEE Trans. Ind. Appl.*, vol. 50, no. 3, pp. 1817–1828, May/Jun. 2014
[10]. J. Prudell, M. Stoddard, E. Amon, T. K. A. Brekken, and A. von Jouanne,"A permanent-magnet tubular linear generator for ocean wave energy conversion," *IEEE Trans. Ind. Appl.*, vol. 46, no. 6, pp. 2392–2400, Nov./Dec. 2010.
[11]. H. Polinder, M. E. C. Damen, and F. Gardner, "Linear PM generatorsystem for wave energy conversion in the AWS," *IEEE Trans. EnergymConvers.*, vol. 19, no. 3, pp. 583–589, Sep. 2004.
[12]. X. Liu, P. Wang, and P. C. Loh, "A hybrid ac/dc micro-grid and its coordination control," *IEEE Trans. Smart Grid*, vol. 2, no. 2, pp. 278–286,Jun. 2011.
[13]. M.M. R. Singaravel and S. A. Daniel, "MPPT with single dc-dc converterand inverter for grid-connected hybrid wind-driven PMSG-PV system,"*IEEE Trans. Ind. Electron.*, vol. 62, no. 8, pp. 4849–4857, Aug. 2015.
[14] C. Hua, J. Lin, and C. Shen, "Implementation of a DSP-controlled photovoltaic system with peak power tracking," *IEEE Trans. Ind. Electron.*,vol. 45, no. 1, pp. 99–107, Feb. 1998.
[15] M. G. Villalva, J. R. Gazoli, and E. R. Filho, "Modeling and circuitbasedsimulation of photovoltaic arrays," in *Proc. 2009 Brazilian PowerElectronics Conf.*, 2009, pp. 1244–1254.
[16] J. Mahdavi, A. Emadi, and H. A. Toliyat, "Application of state spaceaveraging method to sliding mode control of PWM DC/DC converters,"in *Proc. 32nd IEEE Ind. Appl. Soc. Annu. Meeting*, 1997, pp. 820–827.
[17] F. Wu *et al.*, "Modeling, control strategy, and power conditioning fordirect-drive wave energy conversion to operate with power grid," *Proc.IEEE*, vol. 101, no. 4, pp. 925–941, Apr. 2013.
[18] M. H. Ali, B.Wu, and R. A. Dougal, "An overview of SMES applicationsin power and energy systems," *IEEE Trans. Sustain. Energy*, vol. 1, no. 1,pp. 38–47, Apr. 2010.
[19] Z. Shi, F. Auger, E. Schaeffer, P. Guillemet, and L. Loron, "Interconnected observers for online supercapacitor ageing monitoring," in *Proc. 39thAnnu. Conf. IEEE Ind. Electron. Soc.*, pp. 6746–6751.
[20] H.-L. Do, "Non-isolated bidirectional zero-voltage-switching dc-dc converter," *IEEE Trans. Power Electron.*, vol. 26, no. 9, pp. 2563–2569,Sep. 2011.
[21] M. G. Villalva, J. R. Gazoli, and E. R. Filho, "Comprehensive approachto modeling and simulation of photovoltaic arrays," *IEEE Trans. Power Electron.*, vol. 24, no. 5, pp. 1198–1208, May 2009.

