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A NOVEL STANDALONE HYBRID SYSTEM APPLYING DUMP POWER CONTROL WITHOUT DUMP LOAD

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Abstract

This paper proposes a unique standalone hybridpower generation system, applying advanced power control techniques, fed by four power sources: wind power, solar power, storage battery, and diesel engine generator, and which is not connected to a commercial power system. Considerable effort was put into the development of active-reactive power and dump power controls. The result of laboratory experiments revealed that amplitudes and phases of ac output voltage were well regulated in the proposed hybrid system. Different power sources can be interconnected anywhere on the same power line, leading to flex-ible system expansion. It is anticipated that this hybrid power generation system, into which natural energy is incorporated, will contribute to global environmental protection on isolated islands and in rural locations without any dependence on commercial power systems.

Introduction

The project titled "Standalone Hybrid Wind-Solar Power Generation System Applying Dump Power Control Without Dump Load" aimed at obtaining energy-based power generation systems are commonly equipped with storage batteries, to regulate output fluctuations resulting from natural energy variation. Therefore, it is necessary to prevent battery overcharging. As for the utility connected hybrid generation system consisting of a wind power, a solar power, and battery, the dump power is able to control to prevent overcharging the battery without dump load because of dump power transferred into the utility[1]. As for the individual power generation system, it is considered that a PV system featuring low-cost and simple control, which incorporates maximum power point tracking control that makes use of diode characteristics [2],PV system that features output stability with a multiple-input dc–dc converter capable of controlling the output of different power sources in combination [3], or a cascaded dc–dc converter PV system that features good efficiency along with low cost [4],or a wind turbine system that features output stability with a combination of an electric double-layer capacitor and storage battery [5], is suitable for use with hybrid power generation systems to stabilize power supply. A dc–dc converter is mounted in both wind power and solar power generation systems. The two systems are inter-connected at the output sides of individual converters and are also connected to the storage battery. In such a configuration, each dc–dc converter is capable of monitoring the current and voltage of the storage battery, and optimally controlling battery charging, to supply power to the load [6]–[10]. In most cases where converters and storage batteries are set up at a centralized location, the storage batteries are commonly installed adjacent to the wind- andsolar-power generation systems; therefore, there is generally no freedom to install the batteries on flat ground or in places with good vehicular access for easy maintenance and replacement

Existing system

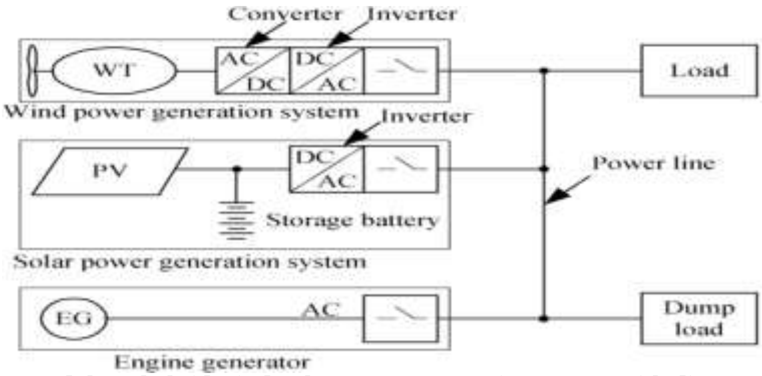


Fig.1.Standalone hybrid wind-solar power generation system with dispersed inverter setup.

In a system applying a dispersed inverter setup, as shown in Fig. 2, individual wind- and solar-power generation systems, each mounted with a dc–ac converter, are interconnected in parallel at the inverter output sides and are also connected to a diesel engine generator via a power line. At the same time, a dump load is also mounted on the same power line [11]–[13]. In this case, a storage battery is installed within the solar power generation system, and dump power is controlled as necessary to prevent battery overcharging. Several different techniques to prevent battery overcharging are widely used. For instance, the battery is installed adjacent to the wind-power generation system, and a solid-state relay or power de-vice is used as control switch of dump load [14]–[15]. Another technique is that surplus power is consumed by a hydrogen generator for a fuel battery instead of storage battery, and when the hydrogen tank becomes full, dump load is applied [14]. While these techniques construct a dispersed installation of different power sources, installation of dump load is necessary. Further, a dedicated high-speed line for battery current/voltage status data transmission, or otherwise a high-tech dump load control method, is necessary.

Proposed system

To resolve these problems, the authors have proposed a low-cost, standalone hybrid wind-solar power generation system applying advanced power control techniques.

This system has the following features:

1. Dispersed installation of different power sources that are interconnected in parallel
2. Elimination of dump load by using a unique dump power control aimed at prevention of battery overcharging
3. No need for dedicated high-speed line for battery current/voltage status data transmission
4. Easy capacity expansion through parallel connection of additional power sources to cope with future load increases.

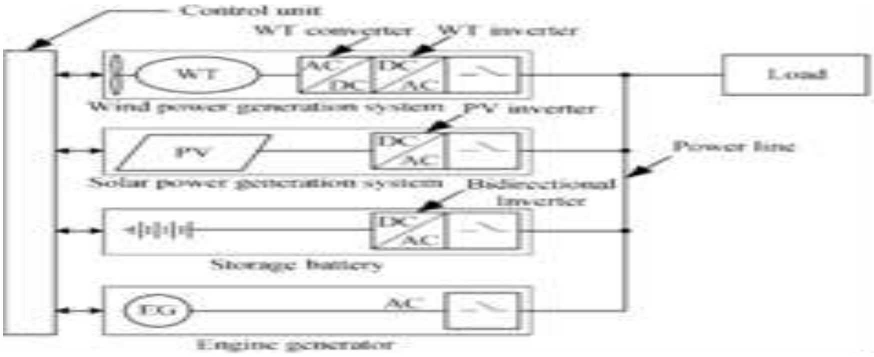


Fig.2.Proposed standalone hybrid wind-solar power generation system.

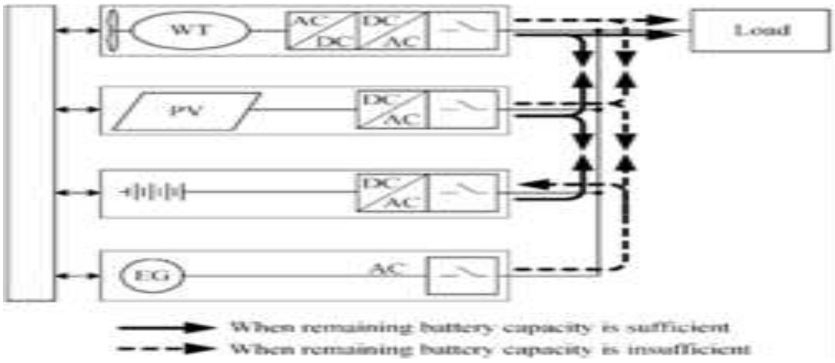


Fig.3.System operation flow

Major operation flows of the proposed hybrid system, as shown in Fig.3, are as follows.

1. When the remaining battery capacity is sufficient EG operation stops, and all inverters operate in parallel. Power surplus and deficit according to the balance between the output and load can be optimally adjusted through battery charging or discharging.
2. When the remaining battery capacity is insufficient EG and all inverters operate in parallel. When power generated by wind and solar power generation systems is insufficient to meet load demand, EG compensates for the deficiency. Concurrently, EG charges the battery via the bidirectional inverter. This inverter regulates charging power for the battery so that EG can be operated at the optimal load factor congruent with high efficiency, following a command from the control unit.

System power control technique

In the proposed hybrid system, we focused on how to control active-reactive power aiming at load sharing in parallel inverter operations, as well as how to control phase synchronization. Through our research activity, we devised an advanced dump power control technique without dump load.

Active-reactive power control

The basic power control block diagram for the inverter section. the auto master-slave control technique is applied in all inverters. When EG is in operation, contactor A of each inverter is closed, and these contactors are in ac-synchronized operation with all inverters that act as slaves and with EG asfrequency (CVCF) condition. Contactor A of each remaining inverter acting as a slave is closed. Then, ac-synchronized operation will be underway. In studying the developmental concept of our proposed hybrid system, we focused on the mechanism of the PLL in the active-reactive power control

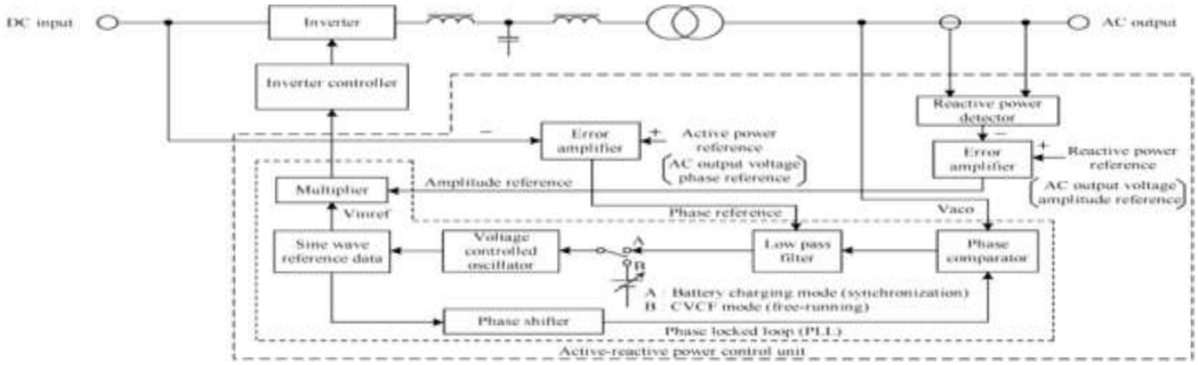


Fig. 4. Basic power control block diagram of inverter section.

Phase locked loop (PLL):

The PLL, which acts as a phase synchronization control, is composed of: a phase comparator, low-pass filter, phase shifter, multiplier, and voltage-controlled oscillator (VCO). The phase comparator acts to multiply the ac output voltage wave by the cosine wave reference obtained from the sine wave reference passing through the phase shifter. The multiplied wave is converted to dc voltage for VCO frequency control via the low-pass filter. During synchronization with phase coincidence of the two waves (i.e., sine wave reference and ac output voltage wave), dc voltage becomes zero.

However, during synchronization with their phase shift, dc voltage does not become zero. Figs. 3 and 4 illustrate the individual waves and dc voltage for VCO frequency control when phase is coincident and shifted, respectively.

The low-pass filter acts as an error amplifier. By giving an active power reference (i.e., ac output voltage phase reference) to the amplifier, the phase shift between sine wave reference and ac output voltage wave is adjusted while synchronization is maintained in a locked state. That is, active power control is possible by altering the dc voltage. The dc voltage obtained through the low-pass filter is converted to the value of a timer counter by using the VCO. This value is defined as the duration for which the value obtained for a certain address in the sine wave reference data (256 addresses in total) is constantly output until the following address comes.

In the case of 60 Hz, an address in the sine wave reference data is incremented by one at about every 65 μs.

Synchronization is adjusted by changing the duration until the following address comes. The duration, or value of the timer counter, is updated about every 200 μs (i.e., about 65 μs × 3), that is, once per three addresses. Fig. 8 shows the detailof the PLL control block diagram. Two elements, that is, the phase comparator output and the phase reference signal, are imported into the low-pass filter. The output of the phase comparator is imported as synchronization data (i.e., difference compared to reference frequency). The phase reference signal is imported as the amount of phase shifting in inverter output voltage while maintaining synchronization against voltage in the commercial power system. Thus, the active power varies along with the change in the phase reference signal. For the reactive power, the sine wave reference regulated by VCO is multiplied with the signal in which the difference between reactive power reference and altering the reactive power reference (i.e., ac output voltage amplitude reference), reactive power control is made possible.

The PLL has a superior characteristic, in that synchronization is ensured even if the wave is deformed, especially when EG shows extreme voltage wave distortion. EG has a higher internal impedance, compared with the commercial ac line. Therefore, the output voltage of the EG has harmonic distortion when nonlinear loads such as switching elements, diodes and so forth are connected. However, if the wave amplitude varies, the dc voltage obtained by passing through the low-pass filter also varies, giving rise to concern that output of active power may fluctuate

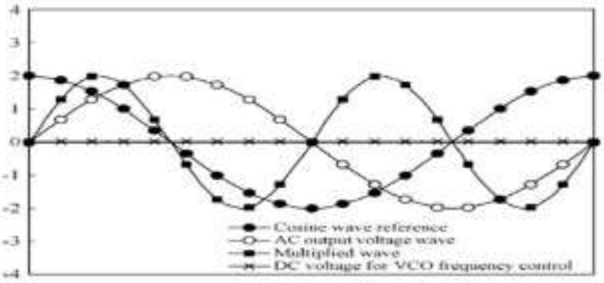


Fig. 5. Synchronization with phase coincidence

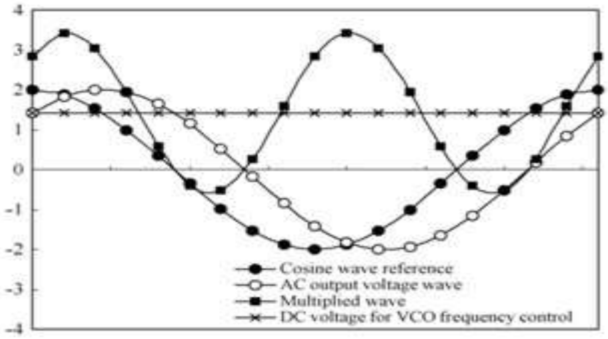


Fig. 6.Synchronization with phase shift.

Operation of parallel inverters:

Fig. 6 shows an operating model of inverters in parallel. X_1, X_2, and X_3 are interconnected reactors installed in WT inverter, PV inverter, and Bidirectional inverter, respectively. We conducted research into determination of optimal active-reactive power parameters for each inverter to regulate the out-put under the conditions that each inverter capacity was 3 kVA (with a power factor of 0.8), and the output voltage was single-phase 100 V 60 Hz. Where, active power is $P_{sm}$and reactive power isQ_{sm}at the sending-end; active poweris P_{rm} and reactive power is Q_{rm} at the receiving-end; and the reactance of the interconnected reactor is X_m. Assuming that $V_{sm}$is defined as the sending-end voltage and$V_r$as thereceiving-end voltage, and the angle of phase difference is δ, each of P_{sm}, Q_{sm}, P_{rm}, and Q_{rm} is represented as follows [18], [15]

$$P_{sm} = P_{rm} = V_{sm}V_r / X_m SIN\delta \qquad (1)$$

$$Q_{sm} = V^2_{sm} - V_{sm}V_r COS\delta / X_m \qquad (2)$$

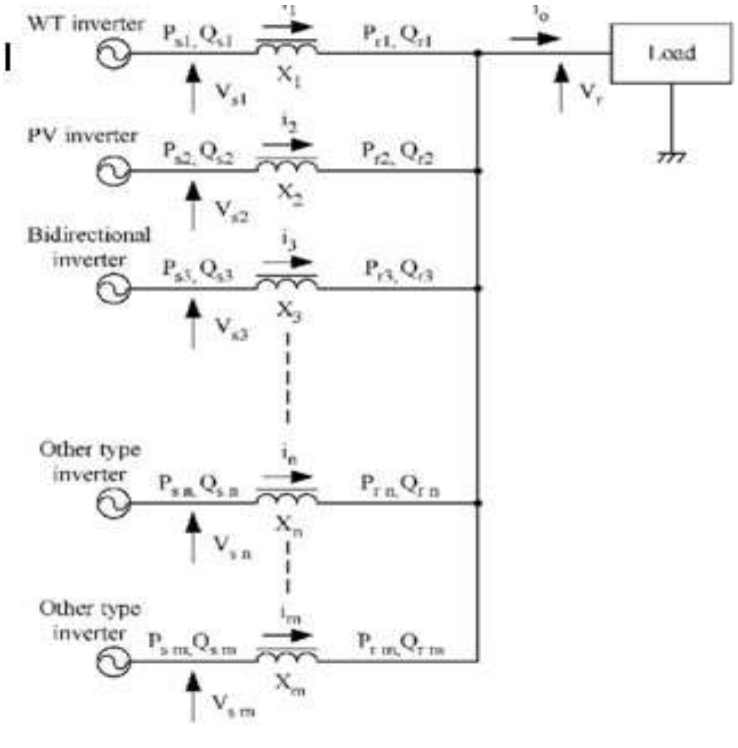


Fig 7.operation of parallel inverter

Here, *m* indicates the number of power sources that are operated in parallel. It is desirable to regulate the voltage amplitude difference and the angle of phase difference to be within the ranges from 5 V to 15 V, and from 5° to 10°, respectively, based on the characteristics of the active-reactive power control unit as shown in Fig. 3. When δ is 7.5° and V_r is 100 V, V_{sm} becomes 109 V by using (1) and (2). The reactance of the interconnected reactor becomes 1.57 mH. Fig. 15 shows the current and voltage waves of each inverter mounted in the prototype. 50% of active power was supplied to the load by individual WT and PV inverters, under the condition that the reactive power of the storage battery bidirectional inverter became zero.

The capacity of load was 3 kVA, and the power factor was 0.8. From individual waves shown in Fig. 15 and results of the measured output voltage and output current of each inverter, as shown in Table II, several observations are worthy of remark. For the bidirectional inverter, the output voltage phase showed greater coincidence with amplitude, as compared to load volt-age, and only a little output current flow was caused. For the WT and PV inverters, output voltage phase advanced 4° and voltage amplitude became about 8 V to 10 V higher as com-pared with load voltage, and an output current flow of 16.1 A from each inverter was seen.

These observations show that the WT and PV inverters each supply about 12 A to 13 A of the active current and about 9 A to 11 A of the reactive current to the load consumed.

There was good agreement between theoretical and measured values, when the loss of output transformers and their leakage inductances were neglected. It was confirmed that each inverter controls the output power under optimal conditions by reactive power control (i.e., amplitude control) and active power control (i.e., phase control).

The current phase of WT inverter was 41°, with 4° lag compared to other inverters. This was because some circulating current flowed to each inverter through WT inverter since voltage of WT inverter was higher than those of other inverters. Fig. 7 indicates slight deformations of inverter output cur-rent waves. This is because the output current was controlled so that the inverter output voltage can have a clear loop mechanism. Thus, the inverter output voltage has clear sine waves, although the output current does not have constant clear sine waves. Fig. 16 shows charging current and voltage characteristics of storage battery, and Fig. 17 shows the bidirectional inverter voltage waves in slave mode, showing that the charging was done under the constant voltage constant current condition.

The rating of each lead-acid battery module was 12 V, 24 Ah. The battery unit was comprised of 24 battery modules connected in series in two parallel rows. Floating charging voltage was set as 331.2 V, and charging current was set at about 10 A

Dump power control

When either winds power or solar power generation becomes greater than load, EG stops, and the bidirectional inverter as a master is operated under the CVCF condition. Then, dump power, which is defined as the surplus portion obtained after deducting load from generated power, is used as charging power for storage battery. In the course of battery charging, an advanced technique to prevent battery overcharge is required. Dump load (e.g., a resistor load or radiator), which functions to consume dump power, is conventionally mounted in parallel with the battery or ac output point, as shown in Fig. 18 [11]–[13].

This technique allows for quick response to fluctuating dump power as well as reduction of needless dump power control, contributing to more effective use of natural energy. When the output voltage of the bidirectional inverter increases, the output voltages of WT and PV inverters increase through reactive power control. If the output voltage becomes greater than the ac output voltage reference, the difference is amplified and added to the dc input voltage reference.

With this, the phase reference as shown in Fig. 8 varies, allowing the PLL to control inverter voltage phase. Because the output voltages of the WT and PV inverters are designed to be controlled by the dc input voltage reference, the ac output voltage decreases as the dc input voltage reference increases. In this way, a feedback loop is formed in the proposed system. Dump power is controlled; and charging current and charging voltage in the storage battery can be stabilized.

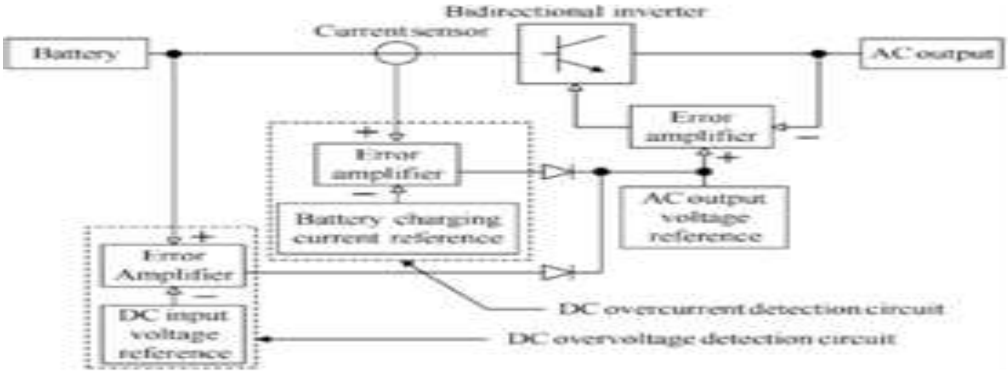
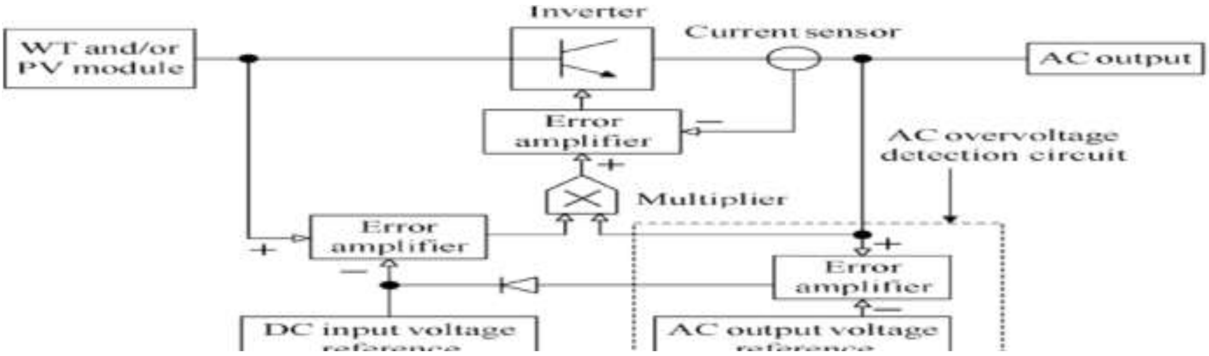


Fig. 8. Dump power control block diagram of bidirectional inverter.



Summarized as follows:

1. Dump load can be eliminated
2. Effective dump power control without dump load to prevent battery overcharging is possible, contributing to extended battery life.
3. Since dump power data is interactively exchanged through the power line, a private communication line between different power sources is unnecessary, resulting in a simple hybrid system arrangement.

Simulation results

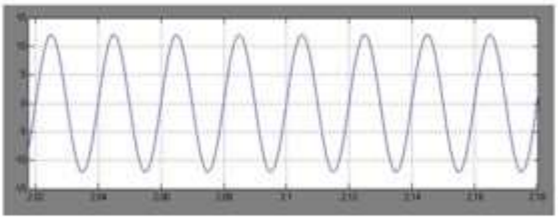


Fig 8- Boost Converter Ac Input Volatge Waveform

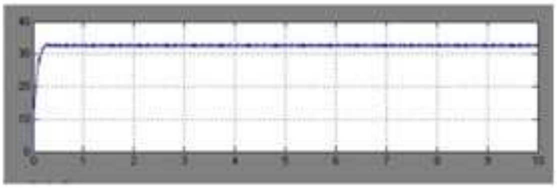


Fig 9- Boost Converter Output Voltage Waveform

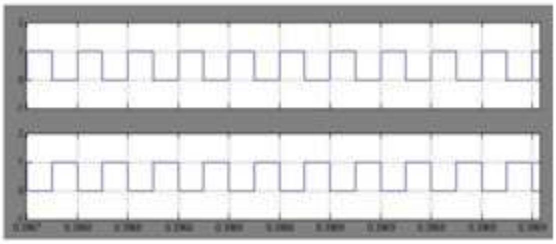


Fig 10- Inverter Switching Pulse For M1,M3

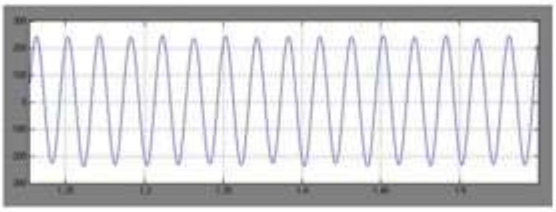


Fig 11- Inverter Output Voltage Wave Form

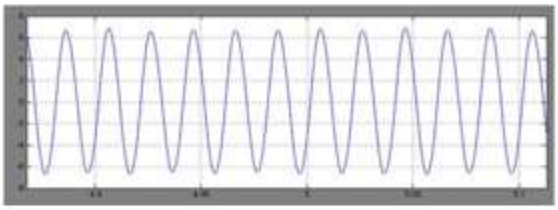


Fig 12- Inverter Output Current Wave Form

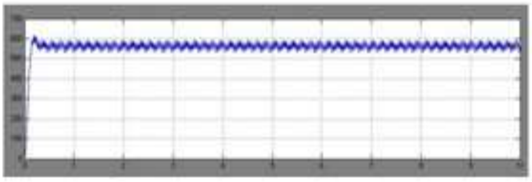


Fig 13- Inverter Output Power Wave Form

Conclusion

In this project, a new family of Standalone Hybrid Wind-Solar Power Generation System Applying Dump Power Control without Dump Load has been introduced. In these this contributes to battery life extension and realization of a low cost system. The system, through ac system interconnection, will also allow flexible system expansion in the future. Further, power sources including EG can be flexibly interconnected anywhere through the same power line, and power quality stability can be maintained by controlling the phase and amplitude of ac output voltage. It is expected that this hybrid system into which natural energy is incorporated, and which makes use of various power control techniques, will be applicable in rural locations, even those with poor communications media. The system will also contribute to global environmental protection through application on isolated islands without any dependence on commercial power systems is implemented.

References

1. Bratcu A. I , Munteau.I , Bacha.S , Picault .D , and Raison.B (2011) , “Cascaded dc– dc converter photovoltaic systems: Power optimization issues,” IEEE Trans. Ind. Electron., vol. 58, no. 2, pp. 403–411.
2. Bonanno F, Consoli A , Lombardo S , and Raciti A (1998), “A logistical model for performance evaluations of hybrid generation systems,”IEEE Trans.Ind. Appl., vol. 34, no. 6, pp. 1397–1403.
3. Belfkira R , Hajji O , Nichita C , and Barakat G (2007), “Optimal sizing of stand-alone hybrid wind/pv system with battery storage,” in Proc. Power Electron.Appl. Eur. Conf., pp. 1–10.
4. Carrasco J. M ,Franquelo L.G , Bialasiewicz J. T ,Galvan E, Guisado R. C. P, Prats, I. Leon M. A. M, and Moreno-Alfonso N, (2006), “Power-electronic systems for the grid integration of renewable energy sources: A survey,” IEEE Trans. Ind. Electron., vol. 53, no. 4, pp. 1002– 1016, .
5. Chandorkar M. C, Divan D. M , and Adapa.R (1993) , “Control of parallel connected inverters in standalone ac supply systems,” IEEE Trans. Ind. Appl., vol. 29, no. 1,
6. Guerrero J. M, Matas J, de Vicuna L. G, Castilla M, and Miret J (2006), “Wireless- control strategy for parallel operation of distributed-generation inverters,” IEEE Trans.Ind. Electron., vol. 53, no. 5, pp. 1461–1470.
7. Haruni A.M.O, Gargoom A, Haque M.E, and. Negnevitsky M (2010), “Dynamic operation and control of a hybrid wind-diesel stand alone power systems,”
8. Jiao S, Hunter G, Ramsden V , and Patterson D (2001) , “Control system design for 20kW wind turbine generator with a boost converter and battery bank load,”
9. Kobayashi K, Matsuo H, and Sekine Y (2006), “An excellent operating point tracker of thesolar-cell power supply system,” IEEE Trans. Ind. Electron., vol. 53, no. 2, pp. 499.
10. Kobayashi K, Matsuo H, and Sekine Y (2006), “Novel solar-cell power supply using multiple-input dc–dc converter,” IEEE Trans. Ind. Electron., vol. 53, no. 1, pp. 281–286.
11. Kim S.K, Jeon J.-H, Cho C.-H, Ahn J.-B , and Kwon S.-H (2008) , “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, .
12. Nehrir M. H , LaMeres B. J , Venkataramanan G , Gerez V (2000) , and L. A. Alvarado, “An approach to evaluate the general performance of stand-alone wind/photovoltaic generating systems,” Trans. EnergyConvers., vol. 15, no. 4, pp. 433–439.
13. Tanezaki S, Matsushima T, and Muroyama S (2003) , “Stand-alone hybrid power supply system composed of wind turbines and photovoltaic modules for powering radio relay stations,” in Proc. IEEE INTELEC,. pp. 457–462.

14. Wang.S and Qi.Z (2009) , “Coordination control of energy management for stand- alone wind/pv hybrid systems,” in Proc. IEEE ICIEA, May, pp. 3240–3244.
15. Tanezaki .S, Matsushima .T, and Muroyama .S (2004), “Stand-alone hybrid power supply system composed of wind turbines and photovoltaic modules for powering radio relay stations,” in Proc. IEEE INTELEC, Oct, pp. 457– 462.