Energy Management and Power Control of a Hybrid Active Wind Generator for Distributed Power Generation and Grid Integration

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Abstract - *Traditional breeze vitality transformation frameworks are normally uninvolved generators. The produced control does not rely upon the matrix necessity but rather altogether on the fluctuant wind condition. A dc-coupled breeze/hydrogen/super capacitor half and half power framework is considered in this paper. The motivation behind the control framework is to facilitate these diverse sources, especially their energy trade, keeping in mind the end goal to make controllable the created control. Accordingly, a dynamic breeze generator can be worked to give some auxiliary administrations to the lattice. The control framework ought to be adjusted to coordinate the power administration systems. Two power administration methodologies are introduced and analyzed tentatively. We found that the "source following" technique has better exhibitions on the network control direction than the "framework following" system.*

1.1 INTRODUCTION

Sustainable power sources (RES) and conveyed ages (DGs) have pulled in exceptional consideration everywhere throughout the world with a specific end goal to achieve the accompanying two objectives:

1) the security of vitality supply by lessening the reliance on imported petroleum products;

2) the lessening of the discharge of ozone depleting substances (e.g., CO2) from the copying of non-renewable energy sources.

Other than their moderately low effectiveness and high cost, the controllability of the electrical creation is the fundamental disadvantage of sustainable power source generators like breeze turbines and photovoltaic boards due to the wild meteorological condition. Moreover, the guidelines for interconnecting these frameworks to the utility turn out to be increasingly basic and require the DG frameworks to give certain services, like recurrence and voltage directions of the neighborhood network. Wind vitality is the world's quickest developing vitality source growing all around at a rate of 25%– 35% every year finished the most recent decade.

Be that as it may, traditional breeze vitality change frameworks work like latent generators. As arrangements, crossover control frameworks (HPS) are proposed to beat these issues with the accompanying two imaginative changes.

1) Energy capacity systems are used to repay or retain the contrast between the produced wind control and the required matrix control

2) Power administration strategies are actualized to control the power trade among various sources and to give a few administrations to the matrix

Hydrogen advances, consolidating power devices (FCs) and electrolyzes (ELs) with hydrogen tanks, are fascinating for long haul vitality stockpiling as a result of the natural high mass– vitality thickness. On account of wind vitality overflow, the EL changes over the overabundance vitality into H2 by electrochemical response. The delivered hydrogen can be put away in the hydrogen tank for future reutilization.

SCs are prepared to do quick charges and releases and can accomplish an expansive number of cycles without debasement, even at 100% profundity of release without "memory impact." Globally, SCs have a superior round-trip productivity than batteries. With high elements and great effectiveness, flywheel frameworks are likewise reasonable for quick unique vitality store, However, this mechanical framework is at present hampered by the peril of "hazardous" shattering of the monstrous wheel because of over-burden (rigidity due to high weight and high speed). SCs are less delicate in working temperature than batteries and have no mechanical security issues.

1.2 Problem statement

So as to diminish the reliance on petroleum derivatives for vitality age, sustainable power source assumes a basic part in decreasing the ozone depleting substances emanation driving the world toward non-renewable energy source freedom. Wind vitality is the second greatest wellspring of sustainable power source after sun oriented vitality. It is the quickest developing RE source on the planet with a yearly development rate of 30%. The offer of wind vitality is 14% at the worldwide scale on the aggregate mid-term sustainable power source assets potential and this esteem mirrors its development in innovation. Numerous specialists have proposed the thoughts of wind vitality frameworks that can be introduced in urban settings for nearby vitality age. These frameworks highlight extra growth frameworks, either using the building geometry or retrofitted onto the building or a mix of these. Nonetheless, the vulnerability in wind vitality is the fundamental issue in coordinating the expanding interest for sustainable power source.

2. LITERATURE REVIEW

[1] Tao Zhou and Bruno Francois, Senior Member, IEEE Transactions on industrial electroincs. Vol.58.NO.1,Jan 2011.
Established breeze vitality change frameworks are normally detached generators. The produced control does not rely upon the framework necessity but rather altogether on the fluctuant wind condition. A dc-coupled breeze/hydrogen/super capacitor mixture c ontrol framework. Two power administration systems are displayed and looked at tentatively. We found that the "source-following" methodology has better exhibitions on the lattice control direction than the "network following" procedure.

[2] F. Baalbergen, P. Bauer, and J. A. Ferreira, "Energy storage and power management for typical 4Q-load," *IEEE Trans. Ind. Electron.*, vol. 56, no. 5, pp. 1485–1498, May 2009.
The littler this proportion is, the lower the productivity. Moreover, a few burdens can recover vitality. In little frameworks, this vitality is for the most part not required somewhere else and ought to be dispersed .An answer taking care of the two issues already specified is utilizing a vitality stockpiling gadget in the framework. Computation of the costs demonstrates that including a vitality stockpiling gadget brings down the cost for all strategies. Confirmation with recreation and trials has been done.

[3] C. Abbey and G. Joos, "Supercapacitor energy storage for wind energy applications," *IEEE Trans. Ind. Electron.*, vol. 43, no. 3, pp. 769–776, May 2007.
As wind vitality achieves higher entrance levels, there is a more noteworthy need to oversee irregularity related with the individual breeze turbine generators.

Fuel

An energy unit is an electrochemical cell that changes over a source fuel into an electrical current. It creates power inside a cell through responses between a fuel and an oxidant, activated within the sight of an electrolyte. The reactants stream into the cell, and the response items stream out of it while the electrolyte stays inside it. Energy components can work constantly as long as the important reactant and oxidant streams are kept up.

electricity which can be stored in storage unit. The storage unit may vary according to the production of electricity from the wind turbines. Then inverter will convert the stored dc energy into ac. This ac energy can be supplied to the load and grid.

Fuel cell applications

Fuel cells are very useful as power sources in remote locations, such as spacecraft, remote weather stations, large parks, rural locations, and in certain military applications. A fuel cell system running on hydrogen can be compact and lightweight, and have no major moving parts.

Main components of Wind Turbines

Wind turbine is a device that converts kinetic energy from the wind also converts wind energy into mechanical energy a process known as wind power. If the mechanical energy is used to produce electricity, the device may be called wind turbine or wind power plant. If the mechanical energy is used to drive machinery such as for grinding grain or pumping water the device is called a windmill or wind pump. Similarly, it may be called wind charger when it is used to charge batteries. Wind turbines are manufactured in a wide range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging or auxiliary power on boats; while large grid-connected arrays of turbines are becoming an increasingly important source of wind power-produced commercial electricity. There are two types of wind turbine in relation to their rotor settings. They are:

- Horizontal-axis rotors, and
- Vertical-axis rotors

The horizontal-axis wind turbine will be discussed since the modelling of the wind driven electric generator is assumed to have the horizontal-axis rotor. The horizontal-axis wind turbine is designed so that the blades rotate in front of the tower with respect to the wind direction i.e. the axis of rotation are parallel to the wind direction. These are generally referred to as upwind rotors. Another type of horizontal axis wind turbine is called downwind rotors which has blades rotating in back of the tower. Nowadays, only the upwind rotors are used in large-scale power generation. The term horizontal-axis wind turbine refers to the upwind rotor arrangement.

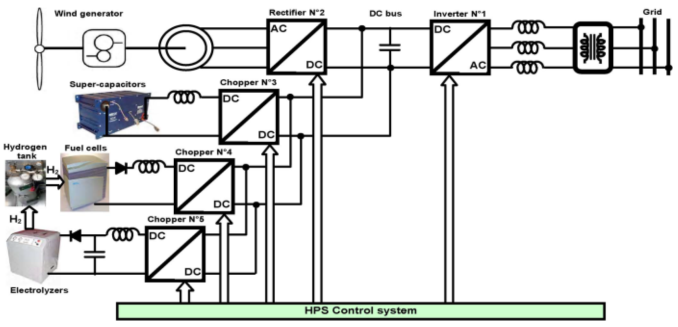

Fig. 1. Structure of the studied wind/hydrogen/SC HPS.

Contrasted with batteries, SCs are prepared to do quick charges and releases and can accomplish countless without corruption, even at 100% profundity of release without "memory impact." Globally, SCs have a superior round-trip effectiveness than batteries. With high flow and great effectiveness, flywheel frameworks are likewise appropriate for quick unique vitality stockpiling. Be that as it may, this mechanical framework is at present hampered by the peril of "hazardous" shattering of the gigantic wheel because of over-burden (rigidity due to high weight and high speed). SCs are less touchy in working temperature than batteries and have no mechanical security issues.

These prerequisites are detailed as genuine and responsive power references, which are computed by a unified optional control focus with a specific end goal to facilitate control dispatch of a few plants in a control zone. This zone relates to a microgrid and is restricted because of the abnormal state of unwavering quality and speed required for correspondences and information exchange

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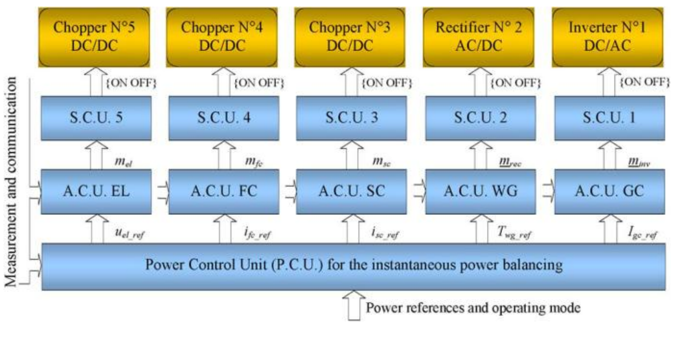

Fig. 2. Hierarchical control structure of the HPS

I. HPS AND CONTROL SYSTEM

A. Structure of HPS

In this paper, we utilize a dc-coupled structure keeping in mind the end goal to decouple the network voltages and frequencies from different sources. All sources are associated with a principle dc transport before being associated with the network through a fundamental inverter. Each source is electrically associated with a power-electronic converter keeping in mind the end goal to get potential outcomes for control activities. Additionally, this HPS structure and its worldwide control framework can additionally be utilized for different mixes of sources.

B. Structure of Control System

Power converters present some control contributions for control change. For this situation, the structure of the control framework can be isolated into various levels. The exchanging control unit (SCU) is intended for each power converter. In a SCU, the drivers with optocouplers create the transistor's ON/OFF signs from the perfect conditions of the exchanging capacity {0, 1}, and the balance system pulse width balance decides the exchanging capacities from the balance capacities (m).

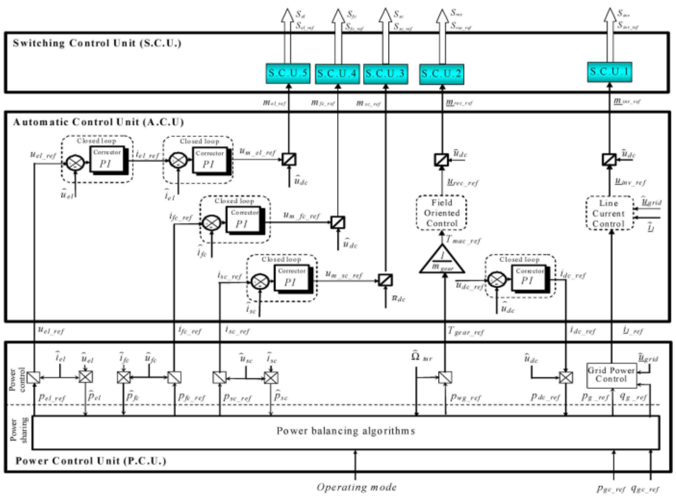

Fig. 3. Modeling and control of the HPS by the Energetic Macroscopic Representation.

The programmed control unit (ACU) is intended for every vitality source and its energy change framework. In an ACU, the control calculations compute the adjustment capacities (m) for each power converter through the direction of some physical amounts as per their reference esteems. The power control unit (PCU) is intended to play out the prompt power adjusting of the whole HPS with a specific end goal to fulfill the lattice necessities. These necessities are genuine and responsive power references, which are gotten from the optional control focus and from references of hang controllers. In a PCU, some power-adjusting calculations are actualized to facilitate the power streams of various vitality sources. The diverse power-adjusting calculations relate to various conceivable working methods of the HPS and can be assembled. The reason for this paper is to exhibit the power-adjusting systems in the PCU. Keeping in mind the end goal to center around the power-adjusting techniques of the HPS, the control plans of the power change frameworks through various power converters won't be definite in this paper. Notwithstanding, a few clarifications of the ACUs are given *in the accompanying sections with a specific end goal to make the controllable factors of the power change frameworks show up.*

C. ACU

The control plots in the ACUs are appeared in Fig. 4 with piece charts.

1) The EL control change framework is controlled by setting the terminal voltage (uel) equivalent to an endorsed reference (uel_ref) through the dc chopper N◦5. The EL stack is considered as a proportionate current source (iel).

2) The FC control change framework is controlled with a reference of the FC current (ifc_ref) through the dc chopper N◦4. The FC stack is considered as a proportional voltage source (ufc).

3) The SC control change framework is controlled with a current reference (isc_ref) through the dc chopper N◦3. The SC bank is considered as an equal voltage source (usc).

4) The breeze vitality change framework is controlled with a reference of the apparatus torque (Tgear_ref) by the three-stage rectifier N◦2.

5) The network association framework comprises of a dc-transport capacitor what's more, a framework control transformation framework. The framework control transformation framework is controlled with line-current references (il_ref) by the three-stage inverter N◦1, in light of the fact that the network transformer is considered as an identical voltage source (ugrid).

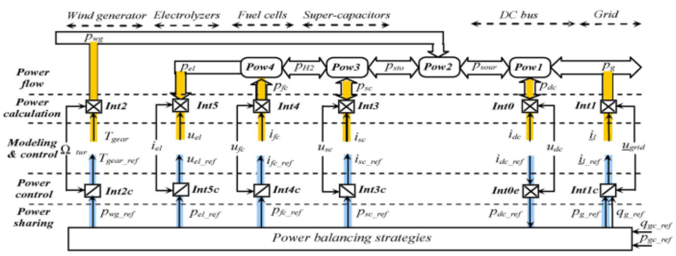

Fig. 4. Multilevel representation of the power modeling and control of the HPS.

The dc-transport voltage is portrayed as

$Cdc = dudcdt = idc$. (1)

So as to control the dc-transport voltage, a voltage controller must be utilized. The yield of the voltage controller is a current reference idc_ref.

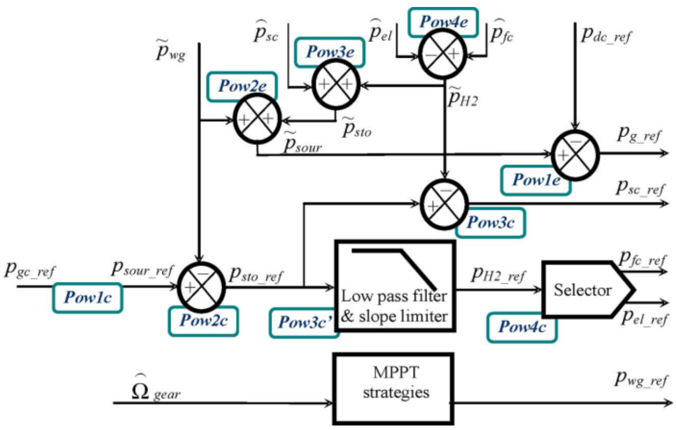

Fig. 5. Block diagram of the grid-following strategy.

Keeping in mind the end goal to help the breeze vitality transformation framework regard the dynamic power prerequisite, the vitality stockpiling frameworks ought to be composed to supply or ingest the distinction between this power necessity (pgc_ref) and the fluctuant wind control (pwg). Among the vitality stockpiling frameworks, the FCs and the ELs are the principle vitality exchangers in light of the fact that a vast amount of hydrogen can be put away for enough vitality accessibility. For efficiency reasons, the FC and the EL ought not work in the meantime. The actuation of the FC or the initiation of the EL relies upon the indication of the reference (pH2_ref). Along these lines, a selector allots the power reference (pH2_ref) to the FC (pfc_ref) or to the EL (pel_ref) as indicated by the indication of pH2_ref.

B. Source-Following Strategy

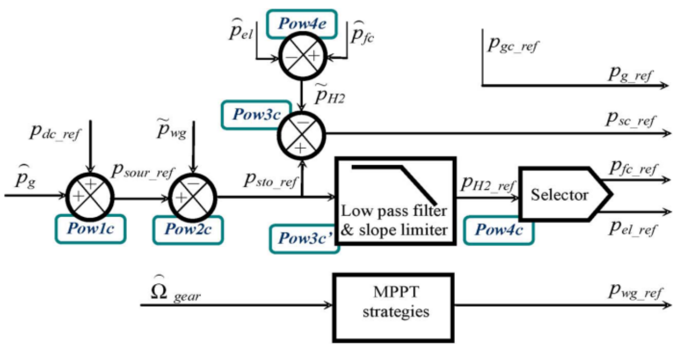

Fig. 6. Block diagram of the source-following strategy.

The aggregate power (psour) from the vitality stockpiling and the WG can likewise be utilized to give the essential dc control (pdc) for the dc-transport voltage direction. For this situation, the essential aggregate power reference (psour_ref) must be ascertained by considering the required power for the dc-transport voltage direction (pdc_ref) and the deliberate matrix control (pg) as unsettling influence contribution by utilizing the converse condition.

This power reference is shared among the FCs, the ELs, and the SCs similarly as clarified. What's more, now, the lattice control reference (pg_ref) is liberated to be utilized for the framework control. The microgrid framework administrator can specifically set the power prerequisites (pgc_ref and qgc_ref) for the matrix association framework (pg_ref = pgc_ref). In this way, the HPS can specifically supply the required forces for giving the subordinate administrations to the microgrid, similar to the controls of the framework voltage and recurrence.

EXPERIMENTAL TESTS

A. Experimental Platform Assessment

An experimental platform of the HPS has been built to test the different power-balancing strategies. Hardware-In-the-Loop (HIL) emulations of a part of a power system enable a fast experimental validation test before implementation with the real process. Some parts of the emulator process are simulated in real time in a controller board and are then interfaced in hardware with the real devices. Such a HIL simulation has been intensively used and enables one to check the availability and reliability of the hybrid active WG (storage component sizing, power-electronic interface, and operation control). The FC and EL emulators are used to provide the same electrical behavior as the real FC stack and the EL stack. Models of the FCs and the EL have been previously validated through comparisons with obtained experimental results and simulated results from models. They are implemented in a digital control board and calculated voltages and currents are generated by using power-electronic converters. Three “Boostcap SC” modules (160 F and 48 V) are connected in series. Therefore, the equivalent capacitor of the SC bank is about 53 F, and the maximal voltage is about 144 V. All sources are connected to the dc bus through different power converters. The dc bus is connected to the grid through a three-phase inverter, three line filters, and a grid transformer.

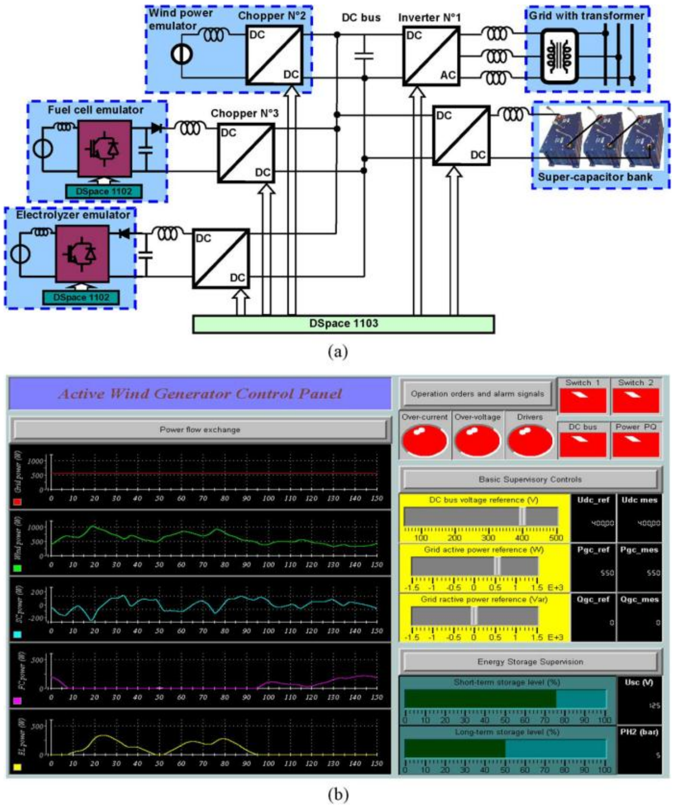

Fig. 7. Implementation of the experimental test bench. (a) System structure. (b) Human–machine interface.

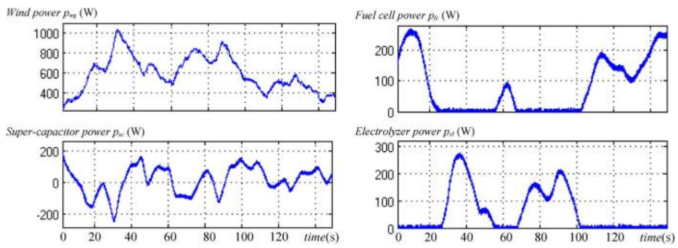

Fig. 8. Power profiles of the different sources.

A trial stage of the HPS has been worked to test the distinctive power-adjusting methodologies. Equipment In-the-Loop (HIL) imitations of a piece of a power framework empower a quick test approval test before execution with the genuine procedure. A few sections of the emulator procedure are recreated continuously in a controller board and are then interfaced in equipment with the genuine gadgets. Such a HIL reproduction has been seriously utilized and empowers one to check the accessibility and unwavering quality of the cross breed dynamic WG (stockpiling segment estimating, control electronic interface, and task control). The FC and EL emulators are utilized to give an indistinguishable electrical conduct from the genuine FC stack and the EL stack. Models of the FCs and the EL have been beforehand approved through examinations with got exploratory outcomes and recreated comes about because of models. They are executed in a advanced control board and ascertained voltages and streams are produced by utilizing power-electronic converters. Three "Boost cap SC" modules (160 F and 48 V) are associated in arrangement. Consequently, the proportionate capacitor of the SC bank is around 53 F, and the maximal voltage is around 144 V. All sources are associated with the dc transport through various power converters. The dc transport is associated with the framework through a three-stage inverter, three line channels, and a matrix transformer.

B. Power Profile of Different Sources

Two tests are performed tentatively for the two methodologies, individually. The same fluctuate wind control profile is utilized amid 150 s. The dynamic power prerequisite from the microgrid is thought to be pgc_ref = 600W. Comparative power profiles are gotten for the vitality stockpiling frameworks. At the point when the created wind control is in excess of 600 W, the EL is actuated to retain the power distinction, however when the produced wind control is under 600 W, the FC is initiated to repay the power contrast. Since the power elements of the FCs and the EL are constrained by a LPF with a 5-s time steady, they are not ready to channel the quick vacillations of the breeze control. Accordingly, the SCs supply or retain the power distinction.

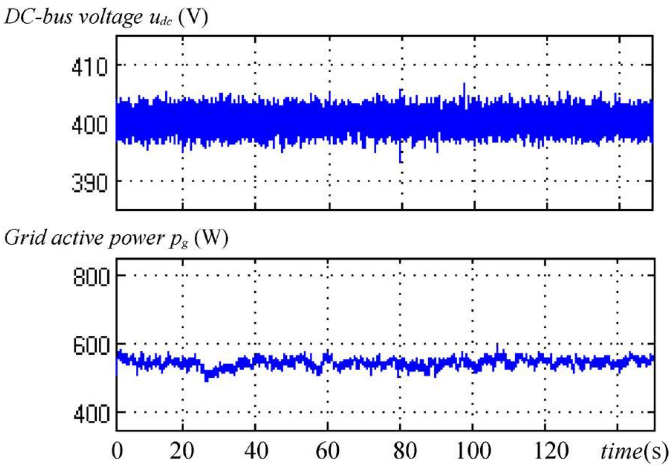

Fig. 9. Grid-following strategy test results.

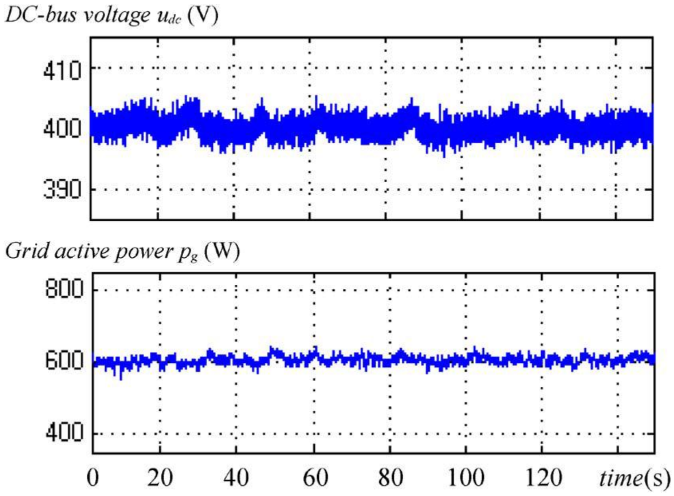

Fig. 10. Source-following strategy test results.

C. Grid Following Strategy

In the matrix following procedure, the dc-transport voltage is all around directed around 400 V by the network control transformation framework. The vitality stockpiling frameworks help the WG supply the microgrid control necessity (psour = pgc_ref = 600 W). In light of the distinctive power misfortunes in the channels and influence converters, the lattice dynamic influence is somewhat not as much as the microgrid's necessity (pg < pgc_ref = 600 W).

D. Source-Following Strategy

In the framework following procedure, the vitality stockpiling frameworks are controlled to supply or ingest the vital powers with a specific end goal to keep up the dc-transport voltage (around 400 V) against the fluctuant wind control (Fig. 13). The network dynamic power is additionally controlled and is equivalent to the microgrid's necessity, on the grounds that the line-current control circle manages specifically the framework powers (pg = pgc_ref = 600 W). Consequently, the source following methodology has better exhibitions on the network control direction than the matrix following system, and it can give subordinate administrations as indicated by the microgrid's necessities.

E. Comparison and Discussion

On account of the assistance of vitality stockpiling frameworks, the dc-transport voltage and the matrix forces can be very much controlled with both control adjusting methodologies, while the WG removes the most extreme accessible breeze control. By contrasting the two power-adjusting procedures and their test comes about we see that the network dynamic power is better managed in the "framework following" technique than in the "source-following" system. In the framework following technique, the lattice control changes consistently on the grounds that the line current control circle manages the dc-transport voltage and the matrix control is balanced constantly. In the source-following procedure, the dc-transport voltage is managed by the SCs, and the network power can be straightforwardly used to supply an indistinguishable power from required by the microgrid framework administrator. Hence, if the dynamic generator is required to give the important forces to take an interest in the microgrid administration, the source-following technique is favored for all the more absolutely controlling the network powers.

CONCLUSION

In this paper, a dc-coupled HPS has been considered with the three sorts of vitality sources: 1) a WG as a sustainable power source age framework; 2) SCs as a quick unique vitality stockpiling framework; and 3) FCs with ELs and hydrogen tank as a longterm vitality stockpiling framework. The structure of the control framework is isolated into three levels: 1) SCU; 2) ACU; and 3) PCU. Two power-adjusting methodologies have been exhibited and looked at for the PCU: the matrix following methodology and the source following system. For them two, the dc-transport voltage and the framework power can be all around directed. The trial tests have demonstrated that the source-following methodology has better execution on the matrix control direction than the network following system.

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