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Design of single switch-boosted voltage current suppressor converter for uninterrupted power supply using green resources integration

Introduction*. Uninterrupted power supply is the major requirement in the areas since it involves human lives. In the current scenario the demand and price of fossil fuels is increasing rapidly and availability also is not sufficient to the needs, an alternative identification to power generation is solar and wind energies. The* ***purpose*** *of designing an aimed, single switch boosted voltage and current suppressor (SS-BVCS) converter topology that interfaces both the wind and solar hybrid model. The* ***method*** *involves in the proposed chopper converter is derived by simply merging a switch and a pair of diodes and CLC filter which is used in realization of zero voltage switching for the main switch and a reversing diode to extract high voltage gain. The designed SS-BVCS converter topology can able to have a tight self-control on two power-processing paths. The* ***novelty*** *of the SS-BVCS converter module is designed to ensure maximum throughput, feeding to the load with high quality uninterrupted output, by boosting the DC voltage to a required amount and thereby supressing the current.* ***Practical value*** *obtained by the developed model utilizes both the sources for supply to the load individually or combined based on the extraction availability of the feeder. Also, the proposed SS-BVCS module delivers with efficient lesser component count and gaining maximum power from the harvest of green energy*. References 30, tables 1, figures 13.
Key words: **single switch-boosted voltage current suppressor converter, green energy, switch smoothening, uninterrupted power supply.**

Вступ*. Джерело безперебійного живлення є основною вимогою в галузях, що пов'язані з людськими життями. У поточній ситуації, коли попит та ціна на викопне паливо швидко зростають, а їх доступність також недостатня для задоволення потреб, альтернативною технологією виробництва електроенергії є сонячна та вітрова енергія.* ***Метою*** *є розробка цільової топології перетворювача з підвищеною напругою та пригнічувачем струму з одним перемикачем (SS-BVCS), яка взаємодіє як з вітровою, так і з гібридною моделлю сонячної енергії.* ***Метод*** *включає запропонований перетворювач переривника, отриманий шляхом простого злиття перемикача, пари діодів і CLC-фільтра, який використовується для реалізації перемикання при нульовому напрузі для основного ключа і реверсивного діода для вилучення високого коефіцієнта посилення по напрузі. Розроблена топологія перетворювача SS-BVCS може забезпечити жорсткий самоконтроль на двох ланцюгах обробки енергії.* ***Новизна*** *модуля перетворювача SS-BVCS призначена для забезпечення максимальної пропускної здатності, живлення навантаження з якісним безперебійним виходом шляхом підвищення напруги постійного струму до необхідної величини і, таким чином, придушення струму.* ***Практична цінність****, отримана завдяки розробленій моделі, дозволяє використовувати як джерела живлення навантаження окремо, так і комбіновано залежно від можливості відбору фідера. Крім того, запропонований модуль SS-BVCS забезпечує ефективне використання меншої кількості компонентів та отримання максимальної потужності за рахунок збирання зеленої енергії.* Бібл. 30, табл. 1, рис. 13.
Ключові слова: **перетворювач напруги струму з одним перемикачем, зелена енергія, згладжування перемикань, джерело безперебійного живлення.**

1. Introduction. An attentiveness of green revolution over the years has been greatly increased due to the reducing availability of the ground supplies such as coal and other fossil fuels. To overcome this problem, the role of producing energy from the solar and wind power plays vital. If also the energy is harvested from the natural resources there is a need for the efficient utilization of the generated power there by integrated power converters are designed using the semiconductor switches to attain the solid conversion for the desired application with compact structure at low cost. The nature of the solar and wind plants outputs is inconsistent and it cannot be directly fed to application, hence it requires an efficient conversion topology with a battery backup is normally required.

Nowadays the large wind turbines are increased in numbers and are more efficient. A group of wind turbines collectively forms a grid. The appealing of the system turns to much higher cost. On looking to the smaller applications like road signs, small buildings, there is need for small wind turbines for the closest customers [1, 2].

The flawless working of a small wind turbine (SWT) is a major issue due to its poor throughput and high cost. As discussed in [3], the SWT throughput falls on several factors which include power converters, the integration of low-cost power converters leading to a poor efficiency of SWTs. The another important factor expands in [4], is the power generator, comparatively to all generators, permanent magnet synchronous generators (PMSGs) have a greater efficiency due to the cu losses in the rotor are small and a larger energy density, PMSGs allows the generator to directly coupled with the wind turbine and can be used at low varying speed applications [5, 6].

The overall design topology for the proposed model is shown in the Fig. 1 where inputs from renewable energy resources are fed to the proposed converter through a filter for the ups application.

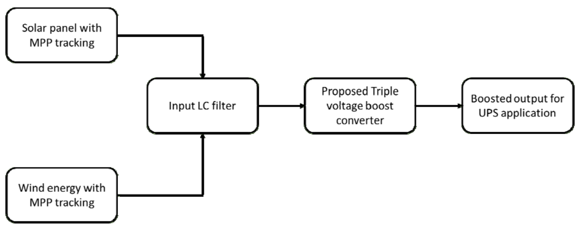

Fig. 1. Block diagram of the proposed model

Viewing solar energy as one of the vital resources in green energy, standalone photovoltaic panels are used for this energy source. To grasp a continuing energy from the source a string of PV arrays is integrated. In order to supply to the load which is generated from the photovoltaic (PV) array, their voltage level must be increased while converted in to another form. Due to the limited power generation by the PV panels because of maximum radiation at the day time only, and energy production costs higher. Key to note the efficiency of these structures is viewed seriously [7-9].

For low level power applications, simple PV systems development and precise control approach of converter provides higher efficiency. In addition, grid is deployed for storing the excessive power generated at the peak hours by gaining maximum power using tracking approach and AC inverter module is much needed for conversion and energy storing in grid it matches the losses between the PV arrays and efficiency is improved comparatively [10-14].

Regulated voltage can be supplied to the load by integrating the inverter stage and the converter module through a transformer will adjust the galvanic isolation between the converter and inverter stage [15, 16]. To reduce the overall system size and cost factor of the proposed multiple source input DC-DC conversion module, it requires multiple inverter module for DC-AC (two-stage) inverter. To overcome this issue, the chopper topology and inverter module are merged and maximum power point tracking (MPPT) provides the increased voltage level to the single converter [17, 18].

In [19, 20], a system with more than one input module of solar and wind is discussed, the drawback of non-isolation provides increase in leakage current which causes its application limited. In [21, 22] proper choice for high power applications is a multiple input inverter using multi-string have discussed. A single-phase multi-input single output system with a new converter introduced in the [23-26] have a greater number of semiconductor switches since both the converters are magnetically coupled lead to increase in the cost and system structure size. Followed in [27] without reducing the number of semiconductors switches the transformers of *N* number of inverters are merged. In [28] a multiple input system is evaluated and for each input an individual chopper boost converter is proposed and output is produced by paralleled the converter circuits, which increases the number of semiconductor elements thereby increasing the cost of the system thereby two auxiliary circuits are necessary to provide soft switching.

The objective is to develop a low-cost, reliable, and efficient wind energy conversion system (WECS) and PV array power supply unit and integration of both the unit by using the proposed converter for uninterrupted power supply applications. A new boost converter module with a freewheeling diode produces the blocking of reverse current flow and to obtain the protection of the converter switch and by using high stability IGBT switching device is used in the topology. This configuration results in increased in the output voltage level and produces continuous voltage and minimum current by tracking the renewable system efficiently.

2. Methodology.

2.1. Energy Conservation Process. The WECS is made of a permanent magnet synchronous machine. The PMSG wind turbine produces torque from wind power. Then the generated torque is shifted through the generator shaft to the rotor of the generator. Then the electrical torque is produced by the generator, and the mechanical torque from the wind turbine differences with the electrical torque from the generator determines the mechanical system gaining speed, lowering speed or no change at constant speed. The maximum power at base wind speed 12 m/s produced is shown in Fig. 2.

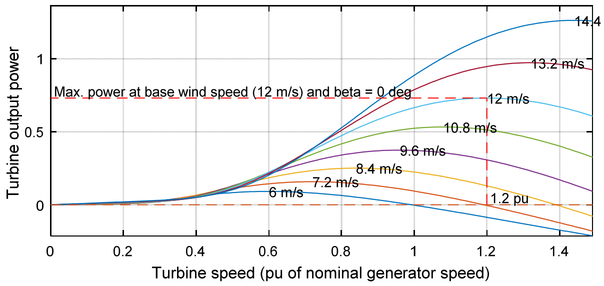

Fig. 2. Turbine power characteristics for different values of wind speed

In [29] a Darrieus vertical axis wind turbine is analyzed. The generator receives the mechanical power output from the turbine is expressed as

$$P_t = C_p(\lambda)\cdot P_w = \frac{1}{2}\cdot C_p(\lambda,\beta)\cdot\rho\cdot A\cdot V_w^3, \qquad (1)$$

where P_w is the power supplied by the wind, W; A is the area of the turbine, m^2; V_w is the wind speed, m/s; ρ is the air density (around 1.2 kg/m^3 in the usual condition of temperature and humidity); C_p is the power coefficient of the turbine; λ is the turbine shaft speed, rad/s; β is the blade pitch angle, deg.

The power coefficient C_p can be estimated by a fourth-order polynomial is expressed as

$$C_p(\lambda) = \sum_{k=0}^{4} C\cdot k\cdot\lambda^k \,, \qquad (2)$$

where k refers to the gain.

2.2. MPPT of the solar panel. The tracking method of solar is modelled as switching frequency (f_s) is modulated with a carrier of sinusoidal variation, input voltage (V_{in}) and reference voltage (V_{ref}) are detected. Then by gain parameter β is used to scale V_{in} and made it compared with V_{ref}. The AC component is obtained from V_{in} by using a peak detector obtained in V_{ref}. The low-pass filter removes the switching frequency component in V_{in}. The required value of duty cycle d is obtained by utilizing the error amplifier which controls the pulse width modulator to adjust of internal resistance R_{in}. This process will have record of the output characteristics of solar panel by not evaluating the V-I relationship [30].

Figure 3 reflects the characteristics output of current to voltage and power to voltage waveforms of the proposed solar panel.

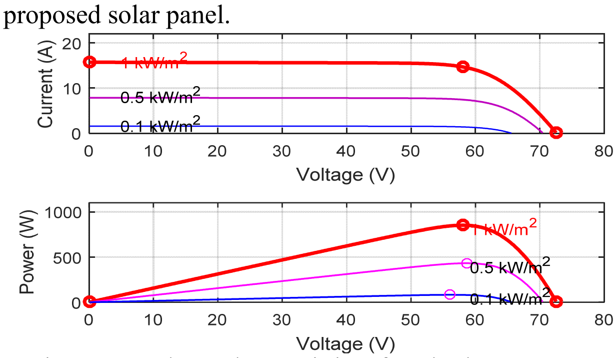

Fig. 3. I-V and P-V characteristics of 1Soltech ISTH 220-P

2.3. Proposed high step up boost converter. The proposed integrated single switch boosted voltage and current suppressor (SS-BVCS) module is made of IGBT switch, C_n, L1, input side filtering followed by a conversion IGBT switch along with charging capacitor C1 with reverse blocking diodes D1 and D2, the output filtering uses C2, L2, C3 components followed by a RL load to determine the output voltage. Figure 4 represents the overall block model and Table 1 represents the parameters of the proposed model.

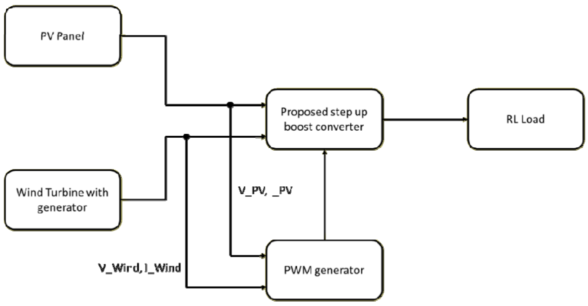

Fig. 4. Proposed model structure

Table 1

Parameters of the proposed model

Input rated voltage, V	71.97	Snubber capacitance C_s, nF	250
Capacitor C_{in}, C1, C2, µF	100	Resistance R_{on}, mΩ	1
Inductor L1, mH	3	Inductor L2, mH	3
Capacitor C1, µF	100	RL load resistance, Ω	20
Diode 1, Diode 2 (L_{on}, H)	0	RL inductance, mH	1
Forward voltage V_f, V	0.8	Output boosted voltage, V	114.4
Snubber resistance R_s, Ω	500		

2.4. Operating principles of the proposed boost converter. In the operating mode 1 (Fig. 5), when the voltage is applied it follows through the path (L1–SW1–C1–D2–(C2, L2, C3)–Load) the inductor L1 charges the current and switch on the switch SW1, the capacitor C2 charges and flows through the diode D2 and it charges the capacitor C2 which allows through the LC filter produces the boosted output across the load.

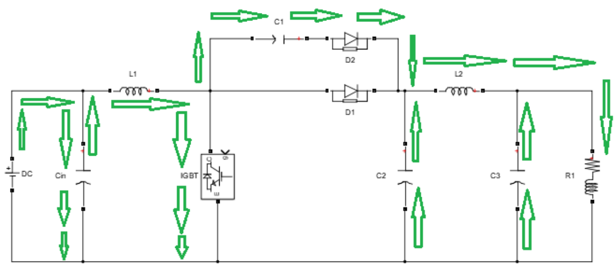

Fig. 5. Operating mode 1

In the operating mode 2 (Fig. 6), when voltage is applied it flows through the inductor (L1–(C2, D2, D1)–C2–L2–C2–Load), though in the reverse voltage it follows the path that is already charge inductor current L1 flows through the mentioned path to produce the uninterrupted power supply to the load.

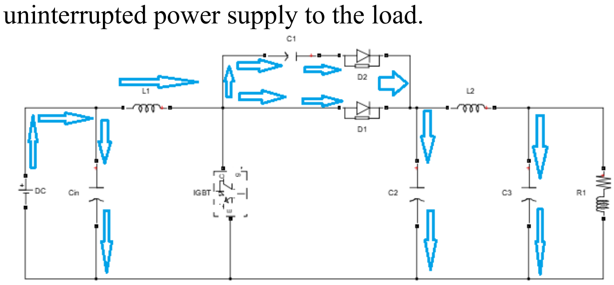

Fig. 6. Operating mode 2

The switching triggering pulse applied to the switch SW1 is tracking back from the proposed SS-BVCS converter output voltage and compared with the voltage required and along with MPPT algorithm is evaluated in order to extract the maximum possible output, since the input varies according to the irradiation of wind and solar the switching sequence to the switch also varies based on the algorithm designed. The switching PWM pulse is shown in the Fig. 7.

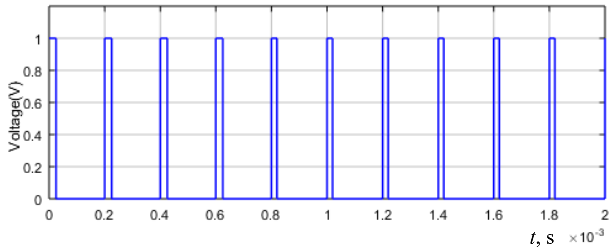

Fig. 7. PWM pulse to the switch

3. Simulation results. The proposed SS-BVCS converter with the integrated renewable sources model has stimulated using MATLAB software for evaluation. The proposed simulated model is shown in the Fig. 8. The PV and PMSG are fed as an input source to the proposed SS-BVCS converter, since the output of both the sources is not constant all the time due to climatic and seasonal changes. The MPPT is implemented to track the maximum power from the input renewable resources. According to the input is sampled from both the energy sources, the frequency to the switches is tuned to gain the maximum power output from the proposed model.

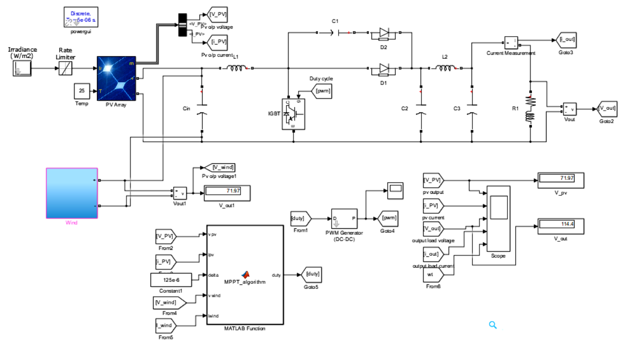

Fig. 8. Overall Simulink model for the proposed design

The proposed SS-BVCS converter has been tested with constant and also with varying wind and solar energy. The duty cycle achieved in the Fig. 8 is for the generated power from the wind speed equal to 12 m/s and PV array power of 850 W.

1Soltech 1STH-215-9 PV module is utilized as a solar energy generation system and its model parameters are next. The proposed solar of 1Soltech 1STH-215-9 module with a irradiance of [1000, 500, 100] (W/m^2), produces the maximum power of 213.15 W, 60 (N_{cell}) cells per module, produces a voltage V_{mp} at maximum power point 29 V and current I_{mp} at maximum power point of 7.35 A. The permanent magnet synchronous machine is used for wind energy generation system. Further, its electrical and mechanical specifications are as follows. The PMSG produces a mechanical output power of $1.5\cdot10^6$ VA with the base power of the electrical generator is $1.5\cdot10^6$ VA/0.9 pu, produces a base wind speed of 12 m/s with a maximum power at base wind speed is 0.73 (pu of nominal mechanical power).

Figure 9 shows the simulated wind generator output voltage and current, and Fig. 10 represents the rotor speed of the PMSG generator. Figure 11 shows the rotor angle of the PMSG turbine generator, and Fig. 12 shows the DC output after rectification from wind turbine generator.

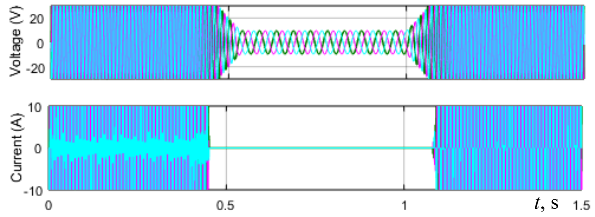

Fig. 9. Wind output voltage and current waveforms

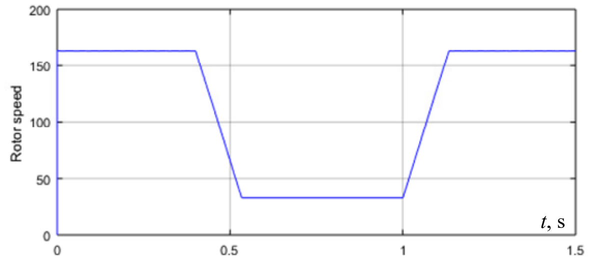

Fig. 10. Rotor speed of the wind waveform

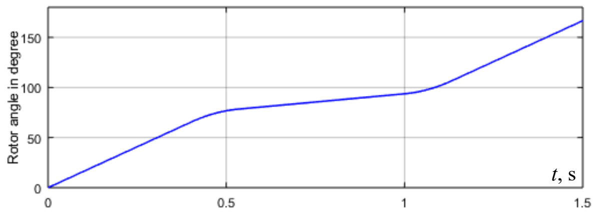

Fig. 11. Rotor angle of the wind

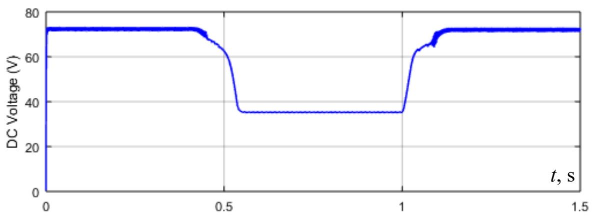

Fig. 12. DC output after rectification from wind output

Figure 13 represents the stimulated waveforms of proposed SS-BVCS converter output voltage of 114.5 V with a output current rating of 5.37 A, produced by the lower input fed by the wind and PV respectively.

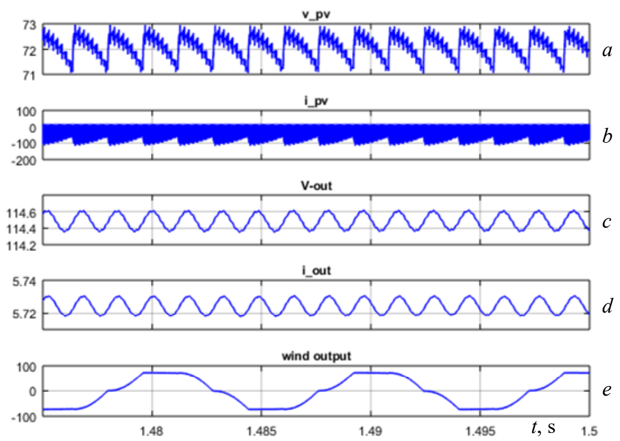

Fig. 13. *a* – PV input voltage; *b* – PV input current; *c* – boosted output; *d* – output current; *e* – wind output waveform

4. Conclusions.

In this work an adequate modelling of permanent magnet synchronous generators wind energy and solar power conversion process has been presented. A maximum power point tracking was designed, which permanently controls the duty cycle of the boost converter by retrieving the variable input from the renewable resources to improve the power supply to the load, by viewing the simulation results verifies that it attains zero voltage switching by makes use of the input filter and also produces the high voltage gain by suppressing the current in the output, the overall output show the output rated voltage is step up conveniently for the uninterrupted power supply by using renewable energy resources.

Conflict of interest. The authors declare that they have no conflicts of interest.

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