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A Novel Control of Multi-Input Dc-Dc Converter for DC and AC Nano Grids

Shravan Kumar B
M.Tech (Electrical Power Systems),
Electrical and Electronics Department,
St. Martins Engineering College.

K. Rama
M.Tech (Control Systems),
Asst. Professor,
Electrical and Electronics Department,
St. Martins Engineering College.

Abstract:

Renewable power and storage have made DC based domestic distribution an attractive alternative for future homes. Due to low power rating of the system, it is very important to reduce number of converter stages and use the generated energy efficiently.

Therefore, instead of using different dedicated converters from various uni-directional renewable sources, this paper proposes a single stage boost converter with multiple inputs that can efficiently decimate generated energy to charge a battery. This philosophy of interfacing renewable sources will have commercial value when some of the additional sources are not large enough to mandate a dedicated converter.

The converter is called Multi-Input-Single Control (MISC) converter. The converter varies the duty cycle based on optimum operation of the largest power source (e.g., MPP in case of solar panel), whereas the other smaller unidirectional sources act as slave.

As per the characteristic of the source, the proposed converter works under various operating modes which are discussed in this paper. The concept is validated using MATLAB/SIMULINK software for different operating scenarios with a solar panel as a master source working under MPPT.

Keywords:

Multi- Input-Single Control (MISC) converter, asymmetrical interleaved structures, MPPT.

Introduction:

A DC nanogrid is small residential supply system (at hundreds of Watts to few kilowatts level) which uses a DC voltage based power distribution to power various domestic loads. The reason DC based nanogrids are an attractive alternative for future domestic power system design is due to the inclusion of more and more renewable and emerging power sources for domestic consumption. Fig.1 shows the block diagram of a DC nanogrid in standalone application.

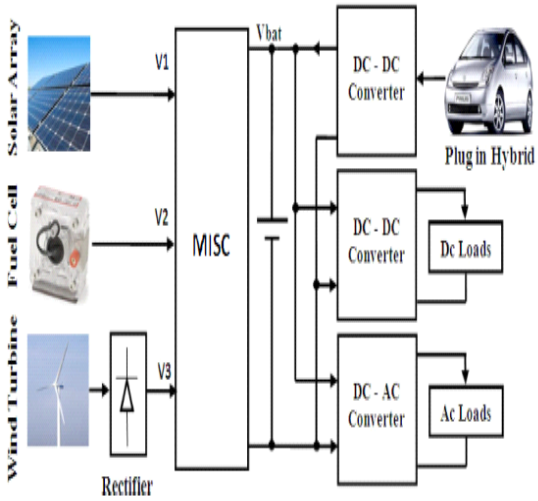

Fig.1An input solar source (Vp) is interfaced to a DC distribution bus (Vd) using a DCIDC converter.

It uses a DC based distribution with various loads connected to it through dedicated point-of-Loadconverters. The idea is basically inspired from computer power system. The renewable power sources are generally DC.

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Due to the intermittent nature of renewable sources, even though the generated power is AC or DC (e.g., solar power is DC and wind power is AC), they are converted to a DC and interfaced with storage before further processing. For continuity in supply of power with renewable sources, a storage element is a must. It is advantageous to make the distribution voltage and battery voltage to be the same in a small power system like a nanogrid to improve efficiency of power usage. This will also eliminate an additional stage of conversion between the battery and the DC nanogrid. Therefore, a boost stage between the solar panel and distribution bus is advantageous. In a 380 V based distribution is used and in a 144 V based distribution is used in realizing the nanogrid. Never the less, in most implementations, a boost converter is used to interface the source with the nanogrid.

From load point of view, most future loads are compatible with DC, e.g., LED lights, Flat panel TV. In summary, a DC nanogrid is preferred because: (a) Renewable sources are DC (b) future loads are more compatible with DC supply. Future DC based nanogrid will have various sources interfaced to the DC-distribution bus. Unidirectional Renewable Sources are interfaced directly to the converter from which power is supplied to the distribution bus. When bi-directional sources are used it is directly interfaced to the distribution bus through a dedicated converter. Renewable Sources have varied characteristics, e.g., a solar array is a current source and a fuel cell is a voltage source. In order to interface all these sources to a single domestic supply grid, a converter has to be interfaced between the respective nodes. In a multi-input series output concept is used to realize this interface which works at ZVS. The output of the converter is directly connected to a battery to save an additional stage as well as MPPT control. Thus, the battery bus and the DC distribution bus are the same.

Converters

1.Voltage source inverter:

When the power requirement is high, three phase inverters are used. When three single phase inverters are connected in parallel, we can get the three phase inverter. The gating signals for the three phase inverters have a phase difference of 1200.

These inverters take their dc supply from a battery or from a rectifier and can be called as six-step bridge inverter. Fig.1.1 shows the three phase inverter using six MOSFET's and with diodes. The mode of inverter operation is mainly classified based on the thyristor conduction period as a) 180°conduction b) 120°conduction.

2.Boost converter:

A boost converter (step-up converter) is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

3.Buck converter:

A buck converter is a step-down DC to DC converter. Its design is similar to the step-up boost converter, and like the boost converter it is a switched-mode power supply that uses two switches (a transistor and a diode), an inductor and a capacitor. The simplest way to reduce the voltage of a DC supply is to use a linear regulator (such as a 7805), but linear regulators waste energy as they operate by bleeding off excess power as heat. Buck converters, on the other hand, can be remarkably efficient (easily up to 95% for integrated circuits), making them useful for tasks such as converting the 12–24 V typical battery voltage in a laptop down to the few volts needed by the processor.

MPPT CONTROL OF PROPOSED CIRCUIT:

A common inherent drawback of wind and PV systems is the intermittent nature of their energy sources. Wind energy is capable of supplying large amounts of power but its presence is highly unpredictable as it can be here one moment and gone in another. Solar energy is present throughout the day, but the solar irradiation levels vary due to sun intensity and unpredictable shadows cast by clouds, birds, trees, etc. These drawbacks tend to make these renewable systems inefficient.

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However, by incorporating maximum power point tracking (MPPT) algorithms, the systems' power transfer efficiency can be improved significantly. To describe a wind turbine's power characteristic, equation (13) describes the mechanical power that is generated by the wind.

$$p_m = 0.5 \rho A C_p(\lambda, \beta) v_w^3 \quad (13)$$

The power coefficient (Cp) is a nonlinear function that represents the efficiency of the wind turbine to convert wind energy into mechanical energy. It is dependent on two variables, the tip speed ratio (TSR) and the pitch angle. The TSR, λ, refers to a ratio of the turbine angular speed over the wind speed. The mathematical representation of the TSR is given by (14).

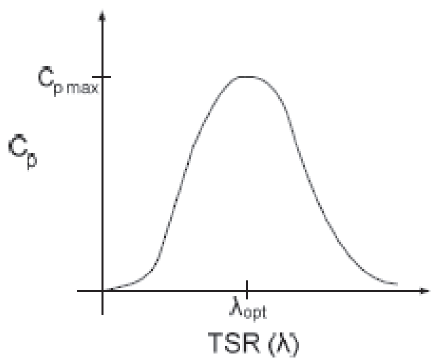

Fig.2Power Coefficient Curve for a typical wind turbine

The pitch angle, β, refers to the angle in which the turbine blades are aligned with respect to its longitudinal axis.

$$\lambda = \frac{R\,\omega_b}{v_w} \quad (14)$$

Where
R = turbine radius,
ωb = angular rotational speed
Figure 2 and 3 are illustrations of a power coefficient curve and power curve for a typical fixed pitch (β =0) horizontal axis wind turbine. It can be seen from figure 2and 3 that the power curves for each wind speed has a shape similar to that of the power coefficient curve. Because the TSR is a ratio between the turbine rotational speed and the wind speed, it follows that each wind speed would have a different corresponding optimal rotational speed that gives the optimal TSR.

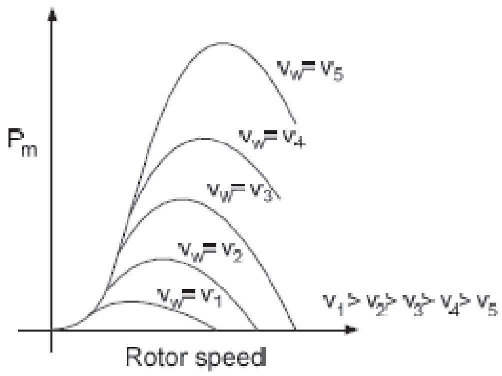

Fig.3Power Curves for a typical wind turbine

For each turbine there is an optimal TSR value that corresponds to a maximum value of the power coefficient (Cp,max) and therefore the maximum power. Therefore by controlling rotational speed, (by means of adjusting the electrical loading of the turbine generator) maximum power can be obtained for different wind speeds. A solar cell is comprised of a P-N junction semiconductor that produces currents via the photovoltaic effect.

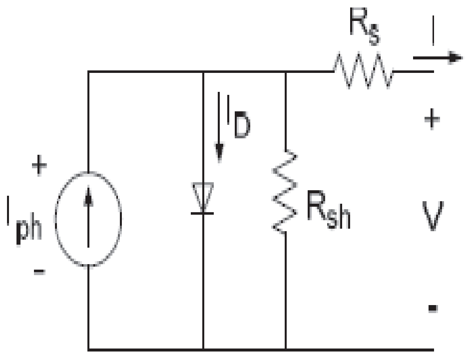

Fig.4 PV cell equivalent circuit

PV arrays are constructed by placing numerous solar cells connected in series and in parallel. A PV cell is a diode of a large-area forward bias with a photo voltage and the equivalent circuit is shown by Figure 4. The current-voltage characteristic of a solar cell is derived in as follows:

$$I = I_{ph} - I_D \quad (15)$$

$$I = I_{ph} - I_0\left[\exp\left(\frac{q(V + R_s I)}{A k_B T}\right) - 1\right] - \frac{V + R_s I}{R_{sh}} \quad (16)$$

Where
Iph = photocurrent,
ID = diode current,

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Io = saturation current,
A = ideality factor,
q = electronic charge 1.6x10-9,
kB = Boltzmann's gas constant (1.38x10-23),
T = cell temperature,
Rs = series resistance,
Rsh = shunt resistance,
I = cell current,
V = cell voltage

Typically, the shunt resistance (Rsh) is very large and the series resistance (Rs) is very small. Therefore, it is common to neglect these resistances in order to simplify the solar cell model. The resultant ideal voltage-current characteristic of a photovoltaic cell is given by (17) and illustrated by Figure 5

$$I = I_{ph} - I_0\left(\exp\left(\frac{qV}{kT}\right) - 1\right) \qquad (17)$$

The typical output power characteristics of a PV array under various degrees of irradiation is illustrated by Figure 6. It can be observed in Figure 6 that there is a particular optimal voltage for each irradiation level that corresponds to maximum output power.

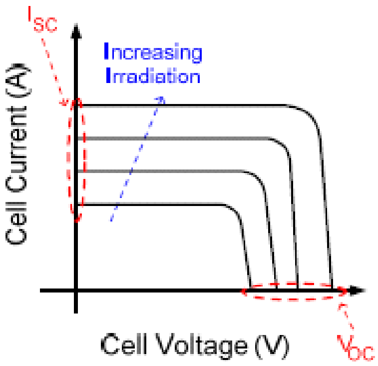

Fig.5 The resultant ideal voltage-current characteristic of a photovoltaic cell

Therefore by adjusting the output current (or voltage) of the PV array, maximum power from the array can be drawn. Due to the similarities of the shape of the wind and PV array power curves, a similar maximum power point tracking scheme known as the hill climb search (HCS) strategy is often applied to these energy sources to extract maximum power. The HCS strategy perturbs the operating point of the system and observes the output. If the direction of the perturbation (e.g. an increase or decrease in the output voltage of a PV array) results in a

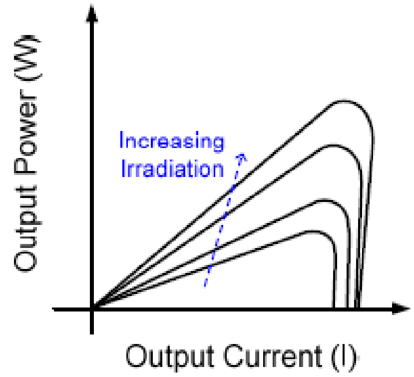

Fig.6The typical output power characteristics of a PV array

Positive change in the output power, then the control algorithm will continue in the direction of the previous perturbation. Conversely, if a negative change in the output power is observed, then the control algorithm will reverse the direction of the pervious perturbation step. In the case that the change in power is close to zero (within a specified range) then the algorithm will invoke no changes to the system operating point since it corresponds to the maximum power point (the peak of the power curves). The MPPT scheme employed in this paper is a version of the HCS strategy.

SIMULATION RESULTS:

The below figures shows the simulation diagrams of the proposed system and extension system.

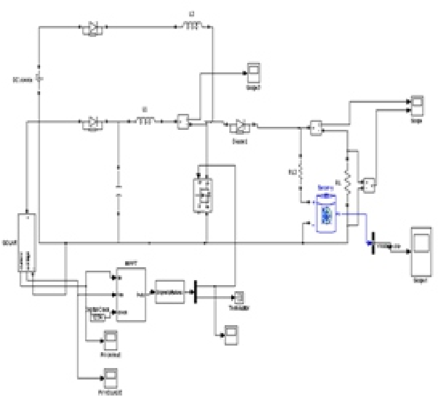

Fig.7 Proposed simulation circuit:

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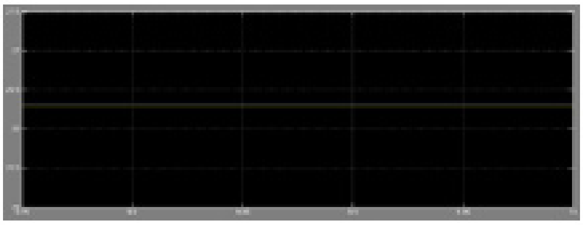

Fig.7.1 Input voltage from solar:

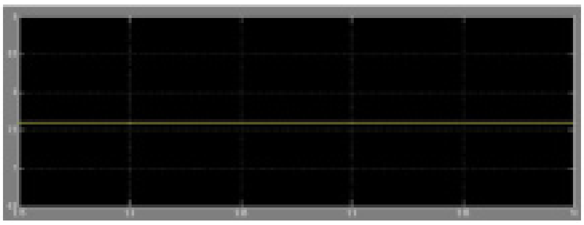

Fig.7.2 Input current from solar:

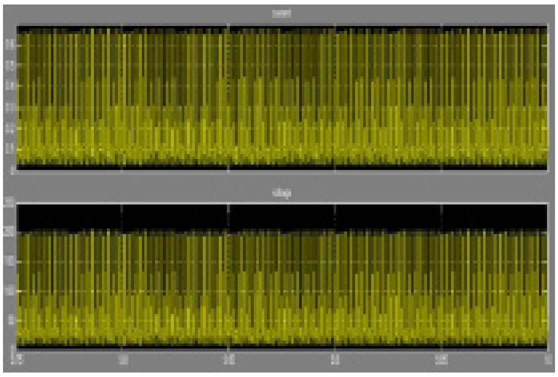

Fig.7.3 Output current and voltage:

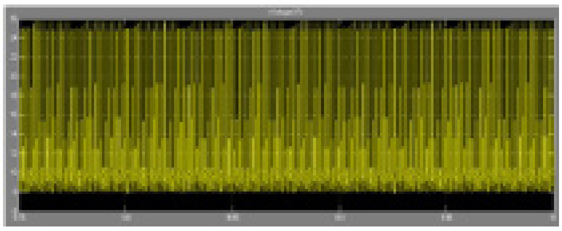

Fig.7.4 Battery charging voltage:

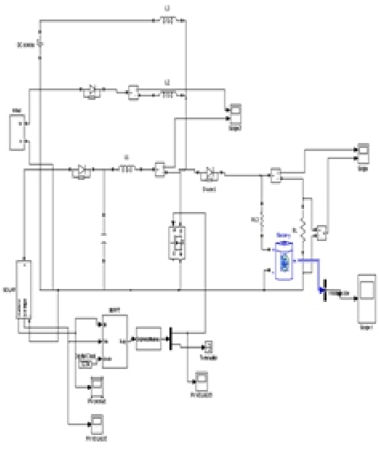

Fig.8 EXTENSION simulation circuit:

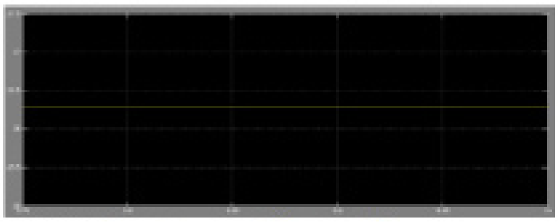

Fig.8.1 Input voltage from solar:

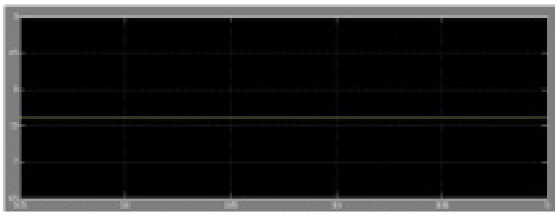

Fig.8.2 Input current from solar:

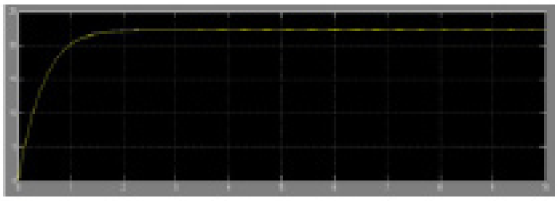

Fig.8.3 Input voltage from wind:

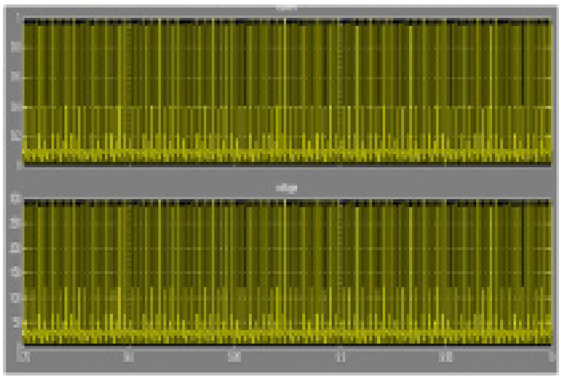

Fig.8.4 Output voltage and current

CONCLUSION:

This paper proposed a Multi-Input-Single Control (MISC) converter. It accepts multiple inputs and boosts the voltage to charge a battery using a single control. A fixed duty cycle based on the highest power source (Master source) characteristics is used to control the circuit. The entire smaller sources act as slave and supply the power that can be extracted from it. Depending upon the interfaced source characteristics different modes of operations are possible.

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The modes areexplained and the concept is experimentally validated using simulation for different operating scenarios with a solar panel as a master source.

REFERENCES:

[1] D. Dong, I. Cvetkovic, D. Boroyevich, W. Zhang, R. Wang, P. Mattavelli,"Grid-Interface Bidirectional Converter for Residential DC Distribution Systems-Part One: High-Density Two- Stage Topology ",IEEE Trans. Power Electron., Vol. : 28, no. 4, pp. 1655 - 1666, April

[2] R. Adda, O. Ray, S. K. Mishra, A. Joshi, "Synchronous-Reference-Frame Based Control of Switched Boost Inverter for Standalone DC Nano Grid Applications ", IEEE Trans. Power Electron., vol. 28, no. 3, pp. 1219

[3] R. Adda, O. Ray, S. K. Mishra, A. Joshi, "Implementation and Control of Switched Boost Inverter for DC Nano Grid Applications," in Proc.

IEEE Energy Conversion Congress and Exposition (ECCE) 2012, Raleigh, NC, Sept. 2012. pp. 3811-3818.

[4] R. Adda, O. Ray, S. K. Mishra, A. Joshi, "DSP based PWM control of Switched Boost Inverter for DC Nano Grid applications," in Proc. 381h Annual 310 Conference of Industrial Electronics Society (I ECON) 2012, Montreal, Canada, Oct. 2012, pp. 5285-5290.

[5] X. Li, A. Bhat, "Multi-Cell Operation of a High-Frequency Isolated DC/AC Converter for Grid-Connected Wind Generation Applications", Proc. of IEEE Int. Con! On Industrial and Information Systems (ICIIS),

[6] Y. Liu and Y. M. Chen, "A systematic approach to synthesizing multi DC–DC converters," IEEE Trans. Power Electron., vol. 24, no. 2,

[7] B. G. Dobbs and P. L. Chapman, "A multiple-input DC-DC convertertopology," in Proc. IEEE Power Electron. Lett, Mar, 2003, vol. 1, pp. 6–

[8] N. D. Benavides and P. L. Chapman, "Power budgeting of a multiple Buck-boost converter," IEEE Trans. Power Electron., vol. 20, no. 6,pp. 1303–1309, Nov. 2005.

[9] H. Matsuo,W. Lin, F. Kurokawa, T. Shigemizu, and N.Watanabe, of the multiple-input DC–DC converter," IEEE Trans. Ind.Appl., vol. 51, no. 3, pp. 625–631, Jun. 2004.

[10] A. Khaligh, J. Cao, and Y. Lee, "A multiple-input DC–DC convertertopology," IEEE Trans. Power Electron., vol. 24, no. 3, pp. 862–868,

[11] Paull, John (2010) , Nanotechnology: No Free Lunch, Platter, 1(1) 8-

[12] Jump up^ Paull, John (2011) "Nanomaterials in food and agriculture: The big issue of small matter for organic food and farming", In: Neuhoff, Daniel; Halberg, Niels; Rasmussen, I.A.; Hermansen, J.E.; Ssekyewa, Charles and Sohn, Sang Mok (Eds.) Proceedings of the Third Scientific Conference of ISOFAR, ISOFAR, Bonn, 2, pp. 96-99.

[13] Jump up^ "Current Intelligence Bulletin 63: Occupational Exposure to Titanium Dioxide". United States National Institute for Occupational Safety and Health, Retrieved 2012-02-19

[14] W. Li, Y. Zhao, J. Wu, and X. He, "Interleavedhigh step-up converterwith winding-cross-coupled inductors and voltage multiplier cells," IEEETrans. Power Electron., vol. 27, no. 1, pp. 133–143, Jan. 2012.

[15] W. Li,W. Li, X. He, D. Xu, and B.Wu, "Generalderivation law of high-step-up interleaved converters with built-in transformer," IEEETrans. Ind. Electron., vol. 59, no. 3, pp. 1650–1661, Mar. 2012.

[16] C. T. Pan and C. M. Lai, "Ahigh-efficiency high step-up converter low switch voltage stress for fuel-cell system applications," IEEE Trans.Ind. Electron., vol. 57, no. 6, pp. 1998–2006, Jun. 2010.

[17] C. M. Lai, C. T. Pan, and M. C. Cheng, "High-efficiency modular step-up interleaved boost converter for DC-microgrid applications," IEEETrans. Ind. Electron., vol. 48, no. 1, pp. 161–171, Jan/Feb. 2012.

[18] Y. T. Jang andM. M. Jovanovic, "Interleaved boost converter with voltage-doubler characteristic for universal-line PFC front end," IEEETrans. Power Electron., vol. 22, no. 4, pp. 1394–1401, Jul. 2007.

[19] N. Femia, G. Petrone, G. Spagnuolo, and M. Vitelli, "Optimization ofperturb and observe maximum power point tracking method," IEEE Trans.Power Electron., vol. 20, no. 4, pp. 963–973, Jul. 2005.