

AN INNOVATIVE FUZZY ENABLED SOLAR & WIND POWERED BLDCM DRIVE FOR HEV APPLICATIONS

¹MAGUDESHWARAN P, ²Dr.IndraGetzy David

¹Assistant Professor -EEE department Bannariamman institute of technology –
Sathy, Tamilnadu ,India

²Professor & Head (Retired) – EEE department Government College of engineering –
Tirunelveli, Tamilnadu ,India

¹magudeswaran@bitsathy.ac.in

Abstract:

It is necessary to utilize renewable energy resources to meet with the global energy challenges. Enabling Wind and Solar Energy fed Hybrid Electric Vehicle system can give a start to change from oil resources. A brushless dc motor (BLDCM) based driver with Photovoltaic generator & Wind-generator (WG) is proposed here. That means, Energy resources can be replaced with Renewable energy sources for to reduce the cost, improve the performance, and replace the conventional principle. And, the Fuzzy Controller added to the existing sensor less control loop can reduce the maximum overshoot and reduce the settling time. The MATLAB/Simulink model can be designed for the proposed driver. In order to utilize the diver circuit, the PV panel is fixed at the top of the Hybrid Electric vehicle and Wind turbine is fixed at the front bumper of the same.

Keywords: Hybrid Electric Vehicle, Renewable Energy sources, BLDC motor, Fuzzy logic controller, Wind and solar hybrid, Sensor less Speed control.

Introduction:

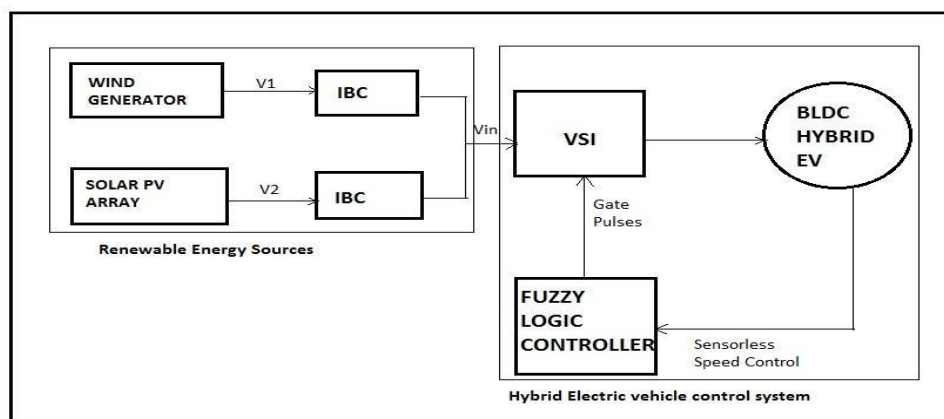


Fig: 1 Schematic Block Diagram Representation

In the recent years, renewable energy resources have become important as pollution-free and unlimited energy supplies. Renewable Energy products are gaining popularity in automotive and industrial sectors. Brushless DC motor (BLDCM) is suitable motor for electric drive designers, due to its attractive features such as high efficiency and energy saving, it can operate efficiently all over the speed range, more reliable than brushed DC motors and more efficient than AC variable frequency motors on the rated frequency. Furthermore, comparing with conventional AC and DC motors, there is an improvement on driving mileage about 20% to 50% in BLDCM, they also expand battery life by 30%. In this paper a control system for driving BLDCM in electric vehicle is developed. A **hybrid electric vehicle** (HEV) is a type of **hybrid vehicle** and **electric vehicle** that combines a conventional internal combustion engine (ICE) propulsion system with an **electric** propulsion system (**hybrid vehicle** drive train). Interleaved Boost converters are the advanced converters comparing to the previous boost and buck-boost converters. Interleaving adding to the circuit to boost the voltage and reduce the ripples in the output current. Interleaving circuits having efficiency more than 97% which will raise the output voltage. In the proposed model, the Interleaving circuits are connected parallel to each other to generate the same level of output across the renewable sources. Interleaved boost converters used to improve efficiency, reduce ripple, and shrink capacitor and inductor size in buck converters, the multiphase approach can provide the same benefits for boost converters. Because the two phases are combined at the output capacitor, effective ripple frequency is doubled, making ripple voltage reduction much easier. Likewise, power pulses drawn from the input capacitor are staggered, reducing ripple current requirements.

Solar PV Panel utilizes the intensity of light and temperature to make a source of energy. The Solar Array consists of connecting number of PV modules in series and/or parallel. And this PV modules are formed by connecting number of PV cells in series and/or parallel. By doing so, it can act as a user-friendly, eco-friendly, economic-friendly product for to generate power. Solar electric systems convert sunlight to “DC” or direct current electricity the same type of electricity that is produced by every-day batteries where electrons flow in one direction. Solar cells, generally consisting of 2 layers of silicon (semi-conductor material) and a separation layer, are wired together and assembled into panels or modules. The output voltage of the panel depends on the number of cells in series. Common nominal output voltages are 12, 18, and 24 volts DC. The output wattage is dependent on the efficiency of the cells and the size or area of each cell in the panel. The larger and more efficient the cells, the greater the wattage will be per square foot. Panels made using more efficient cells tend to be more expensive. When the installer assembles a PV system, an exact number of panels are wired in series strings to achieve the target voltage required by the inverter or other load. Then groups of panel strings are often wired together in “parallel” in order to increase the wattage of the system.

Wind Generator system use the environment air as the source to generate power. In this project, Wind turbine is used to generate some reasonable power which will further boosted and drive the machine. In that means, it also comes under renewable source to complete a control cycle. Like all renewable energy technologies, wind systems rely on two main parts: a collector to harness the energy and a generator with electronics to convert the collected wind energy into power we can use. In wind systems, the collector is the rotor, which is made up of a number of blades that rotate to power a generator that produces electricity. The electronics within the generator and inverter assure that the electricity generated is compatible with the utility. Any renewable energy system's energy output is directly proportional to the size of its collector. In wind turbines, small rotors can only collect small amounts of wind and convert it into small amounts of electricity. Large turbines, such as found on wind farms, collect far more energy than small turbines due to their larger rotors. But, to drive a vehicle, in addition to the solar array, the wind collector is enough to produce necessary power. Here, the bumper of the vehicle is chosen to fix the rotor of the blade.

The advantages of FLC are simplicity of control, low cost and the flexibility. It is suitable for speed control applications. The structure of FLC consists of the following three major components namely fuzzifier which is used for measurement of the input or definition of the fuzzy sets that will be applied. The second one is fuzzy control unit or rule base which provides the system with the necessary decision making, logic based on the rule that determines the control policy. The third one is de-fuzzifier which combines the actions that have been decided and produce single non-fuzzy output that is the control signal of the systems. For to abolish the drawbacks of the PI controller, Fuzzy Logic Control is used to replace the previous one. By doing so, the non-linearity has been improved and the settling time, Maximum overshoot also gets reduced. The overall control architecture of the Sensor less loop for the BLDC machine has been improved. A **fuzzy control** system is a **control** system based on **fuzzy logic**—a mathematical system that analyzes analog input values in terms of **logical** variables that take on continuous values

between 0 and 1, in contrast to classical or digital **logic**, which operates on discrete values of either 1 or 0. For to overcome the demerits associated with PI controller, add a new Fuzzy Logic controller can reduce the Maximum Peak Overshoot, Total harmonic distortion, settling time.

III. SOLAR PV ARRAY:

Generally, Hybrid Vehicles are operated from the renewable sources which reduces the cost for the fuel. Here, there are two renewable resources used for to drive the machine. The first one is the solar PV array. In our system, the simulated PV array is used to generate up to some 100 volts for the varying solar irradiation. A PV system directly converts sunlight into electricity. Power electronic converters are usually required to process the electricity from the PV device. These converters may be used to regulate the voltage and current at the load, to control the power flow in grid-connected systems, and for the maximum power point tracking (MPPT) of the device.

If N_s is the number of the PV cells and N_{ss} and N_{pp} refer to the numbers of the PV modules in series and parallel respectively, the voltage of the PV array is N_{ss} times the voltage of a PV module and the current capability is N_{pp} times that of an individual cell. The Photovoltaic current is written by,

$$I_{pv} = N_{pp} [I_{ph} - I_d (\exp(q(V_{pv}/N_s N_{ss} + I_{pv} R_s / N_{pp}) / AKT) - 1) - ((V_{pv}/N_s N_{ss}) + (I_{pv} R_s / N_{pp}) / R_{sh})] \quad (1)$$

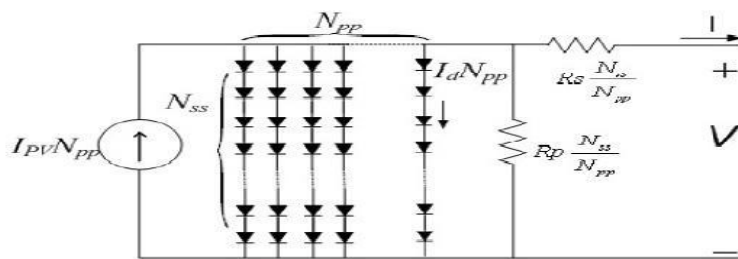


Fig: 2 Series-Parallel Combination Solar PV array

For a PV cell with an ideal I-V characteristic, its open circuit voltage and short-circuit current are given as $V_{OC} = 0.596V$ and $I_{SC} = 2.0A$, respectively. In addition, $N_s = N_p = 1$ for a PV cell. The Photovoltaic current and diode saturation current is defined by, $I_{ph} = (S/S_{ref}) [I_{ph, ref} + K_o (T - T_{ref})]$

----- (2)

$I_d = I_o \{ [qV_d / AKT] - 1 \}$ ----- (3) where S is solar irradiance (W/m^2); S_{ref} is reference value of the solar irradiance ($1000 W/m^2$); $I_{ph, ref}$ is reference value of photovoltaic current; k_o is short-circuit current temperature coefficient related to the cell material; T_{ref} is reference value of the ambient temperature ($40^\circ C$ or $313K$); The current source is written as, $I_m = I_{pv} - I_d (N_{ss} * N_{pp}) = 7.61 \text{ Amps}$ ----- (4)

Tabulation 1 PV Array Values:

Open-Circuit Voltage	Voc,n: 26.9 Volts	
Maximum Voltage	Vmp: 32.9 Volts	
Short-Circuit Current:	Isc,n : 8.21 Amps	
Maximum Output Current	Imp: 9.82 Amps	
Maximum Power	Pmp: 200.124 W	
Ns: No.of cells in series	Ns: 54	
Nss: No of PV modules in series	Nss: 15	
NPP: No of PV modules in parallel	Npp: 2	
Boltzmann Const: k	K:1.3805e-23 J/K	
Charge	Q:1.68e -19 C	
Ideality Factor	A: 1.3	
Series Resistance	Rs: 0.23 Ohms	Rsmx: 0.86 Ohms
Parallel Resistance	Rp:600 Ohms	Rpmin: 42 Ohms

The input given to the Solar PV system is Temperature and Variable Solar Irradiation. The Variable Output voltage is approximately 100 Volts.

IV.WIND GENERATOR:

Globally, wind derived power is the fastest growing energy source. India has the fifth largest installed wind power capacity in the world. Pitch control is one of the most ubiquitously used control techniques to regulate the

output power of wind turbine generators. This method relies on variations in the power captured by the turbine as a function of the hydraulically actuated blade pitch angles. For our system, Wind Generator fulfils another resource for supplying power to the corresponding machine. The simulation work has been done using the Simulink and the generated voltage has been converted. When the wind speed is very low and the rotor does not rotate or rotates with a very low speed, the pitch angle will be approximately 45° . This will provide a maximum start moment to the rotor, permitting a quicker start when the wind speed increases. The MP controller will then pitch the blades to 0° , that is, into the wind. The rotating speed for the rotor and the generator will increase towards the nominal level, which the MP controller will try and maintain with speed control. When the wind speed decreases and the produced power become negative, the generator will be disconnected from the grid and the MP controller will control the speed.

The power derived from wind by the WG turbine blades, P_m depends on the shape of the blade, the pitch angle, the radius of the rotor and its rotary velocity as follows:

$$P_m = 0.5 \rho C_p (\lambda, \beta) R^2 V^3 \quad (1)$$

When the air density (typically 1.25 kg/m^3) is showed by ρ , the pitch angle (in degrees) is represented by β , belongs to the blade radius (in meters), represents the wind speed (in m/s) and $C_p (\lambda, \beta)$ is the power coefficient of wind turbine which is determined by using TSR.

The tip-speed ratio λ which is represented by the terms, defined as: $\lambda = (\Omega R / V)$ ----- (2)

Where Ω (rad/s) belongs to the WG rotor velocity of rotation. If η_g is the efficiency of the generator, so the total power which is generated by the WG, P , will express as: $P = \eta_g P_m$ ----- (3)

Wind Turbine Parameters:

Mechanical Output Power: 1.5 KW

Base Power of Wind Generator: $1.5 \text{ KVA} / 0.9 = 1.66 \text{ KVA}$

Base Wind Speed: 9 m/s

V. INTERLEAVED BOOST CONVERTER:

Interleaved Boost converters are used to raise the input voltage to the required level which will also reduce the ripples in the current content. Here, adding this circuit to both the wind generator and solar PV array output, because of to increase the input voltage. That is, the input supply is given from the Solar Panel & Wind Generator. This input voltage is boosted to the level which will be required to drive the BLDC machine. The input voltage can be boosted up to 240 volts.

Tabulation: 2 IBC Converter Components Value-Design Parameters

Sources	Inductance(L)	DC-Link Capacitance (Cd)	Diode (Vt)	Switch	O/P Voltage
Wind Generator with IBC	1mH	500 μF	0.8V	MOSFET	230V
Solar PV with IBC	100 μF	10mF	0.8V	MOSFET	230V

VI. FUZZY LOGIC CONTROL SYSTEM:

The Fuzzy Logic tool was introduced by LotfiZadeh (1965), and is a mathematical tool for dealing with uncertainty. The position sensors can be entirely eliminated, thus reducing added cost and size of motor assembly, in those application in which only variable speed control is necessary and system dynamic is not predominantly demanding. For typical operation of a BLDC motor, the phase current and back-EMF should be aligned to produce constant torque. The zero-crossing approach is one of the simplest methods of back-EMF sensing techniques, and is based on detecting the instant at which the back-EMF in the unexcited phase cross zero. The control loop involves two variables i. Error and ii. Change in Error. The variables taken for this control technique is Speed.



Fig: 6 Solar PV Array output Voltage and Current

iii. Sensor-Less Speed Control Curve-Fuzzy Controller

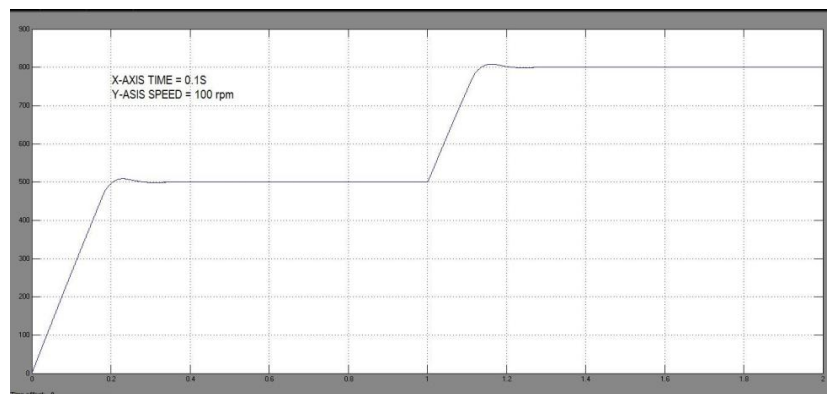


Fig: 8 Fuzzy Speed Control loop (Speed Vs Time): Simulation

VII CONCLUSION:

Thus, the BLDC machine can be powered and driven by the renewable energy resources like Sunlight and Wind as a source. That is, Conventional Sources like Oil, Gas are replaced with natural energy sources for to reduce the cost and environment-friendly product to the industry. The Solar and wind power generators were simulated using MATLAB/Simulink in order to drive the BLDCM which is used in Electric Vehicles/Hybrid Electric Vehicles. The closed loop speed control (Sensor less) is achieved with the Fuzzy controller to overcome the formerly used PI controller. By doing so, the Maximum Overshoot and Settling time gets reduced. Thus the driver circuit is designed and simulated which can be further forwarded into Hybrid Vehicle Applications.

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