ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 12, December 2019

A Simulated Study on SOLAR PV Powered BLDC and Induction Motor Drive

Ravi A[1], Shameema Sultana[2], Megaben[3], Ragavi[4], Muthulakshmi[5]

Professor, Department of Electrical and Electronics Engineering, Francis Xavier Engineering College, Tirunelveli, Tamil Nadu, India [1]

Students, Department of Electrical and Electronics Engineering, Francis Xavier Engineering College, Tirunelveli, Tamil Nadu, India [2,3,4,5]

ABSTRACT: The need of a DC- DC conversion stage in any solar PV system, which is driven by any electric motor is unavoidable, for the purpose of optimization of solar PV generated power using a maximum power tracking technique. However, the DC-DC conversion stage possess the disadvantages of increased cost, size, complexity and low in efficiency. On proceeding to a solution for the above said problem a single stage solar PV energy conversion system feeding an electric motor -system, that eliminates the DC- DC conversion stage can be taken in hand. This paper involves in the comparison of the above mentioned system in BLDC and INDUCTION motor. In which a control technique using a VSI that is capable of operating the solar PV array at its peak power. The Phase current sensors of the electric motors can be discarded in the proposed system. Additional control systems are not needed for the speed control of the system and its soft start. The speed is controlled through the optimum power of solar PV array. The comparative study of both the proposed system is studied by performing MATLAB/SIMULINK platform based evaluation using the simulated results.

KEYWORDS: Brushless dc(BLDC), Voltage source inverter(VSI), Induction Motor, DC-DC Conversion, solar PV array, maximum power point tracking (MPPT)

I.INTRODUCTION

The demand for electrical energy has grown drastically by years rolling on; which has put in place the need of the usage of other renewable sources of energy. Sun supports all the life on earth. Though only half of the solar radiation reaches the earth, the power from the sun radiation meets the power demands of all mankind. Solar energy which is a vast, in exhaustible, clean resource is more advantageous and clear alternative for the electricity generation from fossil fuels with no air and water pollution, no global warming pollution, no risks of electricity price hikes and no threats to our public health. More over Solar energy is enormous. The solar PV modules, power electronic devices and microprocessors are declining in their costs which focuses more towards the increased utilization of SOLAR PV TECHNOLOGY.

The overall Electric power expenditure mainly comprises of the electrically driven motors for more than 40%. Therefore, in the go through process for rectifying a solar PV based energy efficient and cost efficient system a electrically driven motor plays a prominent role. An electric motor is defined as efficient when its solar powered depending on the minimal number of solar modules for given power demand and hence the capital cost. The DC motors are mostly used in low power solar PV system. This DC motor with brushes possess a low efficiency and it requires maintenance due to the sliding brush contacts and the commutator. An Induction motor based PV system is reliable, rugged and maintenance free with better efficiencies and offers more flexibilities for control in comparison to DC motor. The BLDC motors and Induction motors can also be identified as a better substitute for other motors as they are compact, rugged and efficient compared to an AC motor.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 12, December 2019

II. PROPOSED SYSTEM

They differ with each other in the method of performing MPPT in figure 1 it is performed by DC - DC converter in which the 2 - ϕ currents are essential for the motor control sensing. As an alternative an improved topology in which it is seen that phase current sensors are avoided. The main purpose of the DC - DC converter is optimisation of a operating power of a PV array, speed control of a motor and soft starting. The Speed of the motor is controlled by the variable voltage at the dc bus of the voltage source inverter. For the fundamental frequency operation of the voltage source inverter a bulky capacitor is required at the dc link.

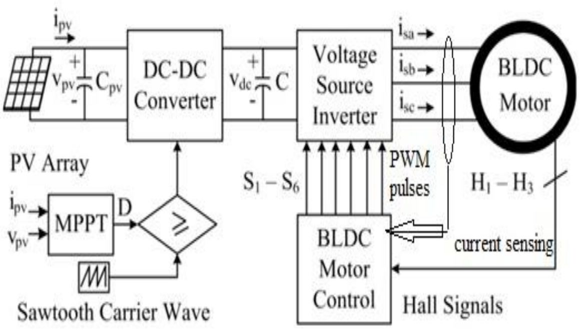

Fig. 1. Conventional BLDC motor drive with phase current sensors based on a two stage solar PV energy conversion system.

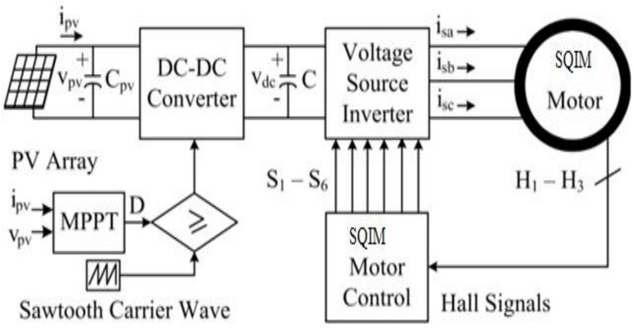

Fig. 2. Conventional Induction motor based on a two stage solar PV energy conversion system.

Keeping all other components in figure 1 unchanged the dc - dc converter in the system is replaced by a Z source inverter. To get forth with the reduction of hall sensors in a BLDC motor drive, Sensor free drives are being reported. In the above described topologies, the two -stage power conversion essentially require the intermediate dc-dc converter to optimize the operating point of a PV array, that results in increased cost, sizes, complexity, and reduction efficiency. So it is obvious, a solution to the above said problems is a single stage power conversion system which does not require the dc - dc conversion.

The improvements in the proposed topology makes it capable of operating the solar PV array at its peak power using the same VSI used for motor control; along with the other benefits of elimination of sensors and soft starting of the motor. The speed control of the motor is handled through the optimum power of solar PV array. A lesser value capacitor using a PWM of VSI replaces the bulky capacitor current at the dc link.

The proposed solutions have a major advantage of high efficiency power conversion. though the conversion efficiency differs based on the motor used.

III. OPERATION PRINCIPLE AND MOTOR SPECIFICATION

The proposed solar PV fed motor design based on a single stage solar PV energy conversion system is illustrated in figure 3 and 4. An electric motor is fed by the VSI, that is directly connected to solar PV array. The reverse current flow is prevented/blocked by the diode in series with the PV array. The power transfer from the PV array to the electric motor drive is enabled by the small dc link capacitor connected. For the efficient utilization of solar PV array an optimal MPPT technique has to be adopted. Hence incremental conductance MPPT technique is adopted in this proposed system. This technique uses PV voltage and current as the FB signals to generate an optimum duty ratio, corresponding to max power of solar PV array.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 12, December 2019

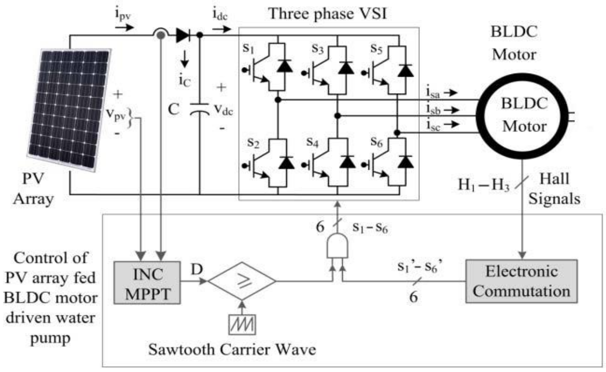

Fig. 3. Proposed Conventional BLDC motor based on a single stage solar PV energy conversion system.

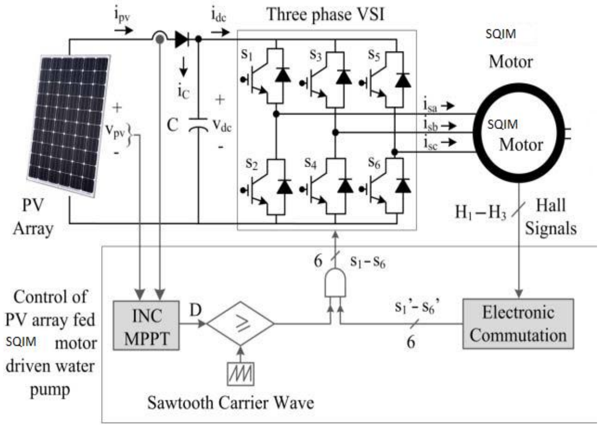

Fig. 4. Proposed Conventional Induction motor based on a single stage solar PV energy conversion system.

TABLE 3.1 Specification of motors

Parameter	BLDC Motor	Induction motor
Power	7.71 - 10.21 Nm , 560 Vdc	5.4 HP - 4000 W
Speed (rpm)	5000 RPM	1430 RPM
No:of:poles,P	3	2
Resistances ohm	0.18	1.405
Inductances (mH)	8.5	5.8
Moment of inertia,J (kgm^2)	0.00062	0.0131

IV. CONTROL APPROACH

The control of the proposed system is classified as below:

- Control of Solar PV array operating point through an MPPT technique.
- Electronic commutation of Motor.
- Switching Pulse generation of Voltage Source Inverter.
- Speed control of the electric motor.

4.1 MPPT TECHNIQUE:

MPPT - is a technique used commonly with wind turbines and PV solar systems to maximize power extraction under all conditions. The incremental conductance strategy is adopted in this proposed system. In the incremental conductance method, the controller measures incremental changes in the PV array current and voltage to predict the effect of a voltage change. This method requires more computation in the controller, but can track changing conditions more rapidly than perturb & observe method. This method utilizes incremental conductance (dI/dV) of the PV array to compute the sugn of change in the power with respect to voltage (dP/dV). The incremental conductance method computes the maximum power point by comparison of the incremental conductance (IΔ/VΔ) to the array conductance (I/V). When these two are the same (I/V = IΔ/VΔ), the output voltage is the maximum power point voltage. The controller maintains this voltage until the radiation changes and the process is repeated. This method is based on the observation taht at the Maximum power point dP/dV is equal to zero and that P = IV.

The current from the array can be expressed as a function of the voltage P = I (V) Therefore dP/dV is equal to V (dI/dV) + I (V). setting the equation to 0 yields, dI/dV = - I (V) / (V). Therefore, the maximum power point is achieved when the incremental conductance is equal to the negative of the instantaneous conductance.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 12, December 2019

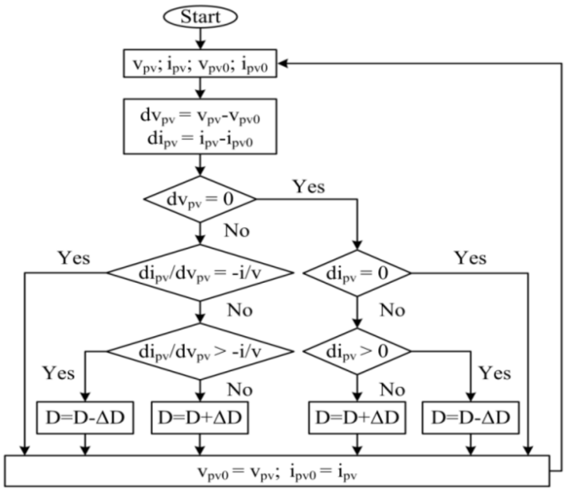

Fig : 6 INC-MPPT algorithm.

4.2 ELECTRONIC COMMUTATION

Brushless motors rely on Semiconductor switches to turn stator conditions ON & OFF at the appropriate time. This process is called Electronic commutation, borrowing a terminology used for the mechanism in dc motors, called a commutator, that switches current from winding to winding, forcing the rotor to run. A symmetrical dc current can be drawn from the dc - bus of voltage source inverter for 120° and placed at the centre of the Back emf. In accordance with the rotor position at an interval of 60° intervals, set of hall signal (H1 - H3) is generated by the hall sensors.
The generated hall signals are transformed into the six fundamental frequency pulses (S1' - S6'). The switching states of Voltage source inverter is decided by these fundamental frequency pulses. The only two pulses are high at any instant, resulting in a low conducting loss.

4.3 SWITCHING PULSE GENERATION FOR VSI

A) BLDC MOTOR:

An AND logic is used to modulate the six fundamental frequency pulses (S_1' - S_6 ') that are generated through an electronic commutation. The AND logic gate receives a high frequency PWM pulse and a fundamental frequency pulse (S_1 ') as inputs and ultimately provides, at the output, a PWM switching pulse (S_1) for upper switch of the first leg. In the same way, using AND gates the switching pulses for the remaining switches are generated. Only if both the inputs to the AND gate are high then it results in high Output (ON). Hence only the ON period of a fundamental frequency pulse with the frequency of saw tooth wave is altered by the AND gate. Thus the control of the proposed system design is realized by compounding the INC - MPPT algorithm and electronic commutation.

B) INDUCTION MOTOR:

Induction motor operates in 180° mode of operation. The sequence of conduction will be as follows T6T1T2, T1T2T3, T2T3T4, T3T4T5, T4T5T6, and T5T6T1. One switching sequence T1T2T3 is taken into consideration, T1T3 are upper group and T2 is lower group. T1 is operated in delay at ωt =0°, T3 is operated in delay at ωt =120° , and T2 is operated in delay at ωt = 60° . The interval of conduction of the Transistors in the upper group i.e. T1, T3, and T5 is 120° . It shows if T1 is operated delay at ωt =0°.Then T3 must be operated delay at ωt =120° and T5 delay at ωt =240° , the same thing for lower group of transistors. Table 4.1 shows the switching states for six switches and also phase to phase Vab, Vbc and Vca voltages are obtained.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 12, December 2019

Table 4.1 Switching States for Three-Phase Voltage Source Inverter for 180 Degree Conduction.

SL	Switching States						V_{ab}	V_{bc}	V_{ca}
	T1	T2	T3	T4	T5	T6			
1.	On	On	Off	Off	Off	On	Vs	0	-Vs
2.	On	On	On	Off	Off	Off	0	Vs	-Vs
3.	Off	On	On	On	Off	Off	-Vs	Vs	0
4.	Off	Off	On	On	On	Off	-Vs	0	Vs
5.	Off	Off	Off	On	On	On	0	-Vs	Vs
6.	On	Off	Off	Off	On	On	Vs	-Vs	0
7.	On	Off	On	Off	On	Off	0	0	0
8.	Off	On	Off	On	Off	On	0	0	0

V. SIMULATED RESULTS

The proposed motor system design is modelled and the performance is simulated in MATLAB/SIMULINK under various conditions. The Quality of the designed system and the efficiency comparing both the systems are demonstrated by the simulated results.

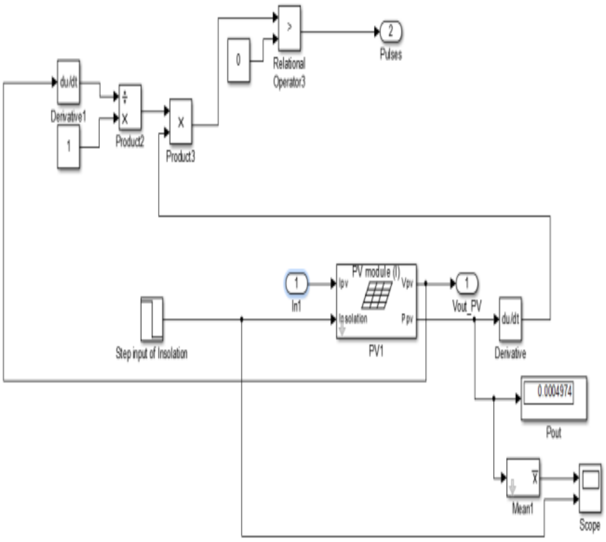

Fig. 8. SIMULINK model of the SOLAR PANEL of a single stage solar PV energy conversion system.

 DOI:10.15662/IJAREEIE.2019.0812002

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 12, December 2019

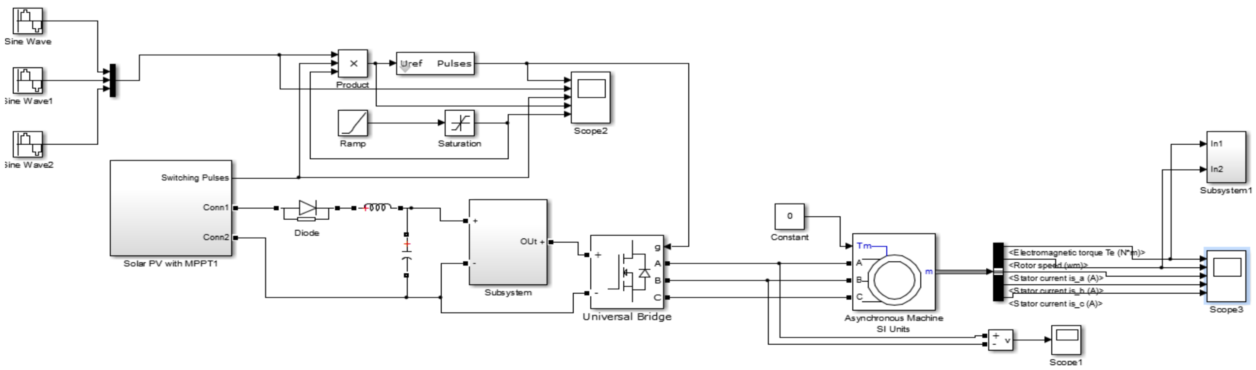

Fig. 9. SIMULINK model of the Conventional Induction motor based on a single stage solar PV energy conversion system.

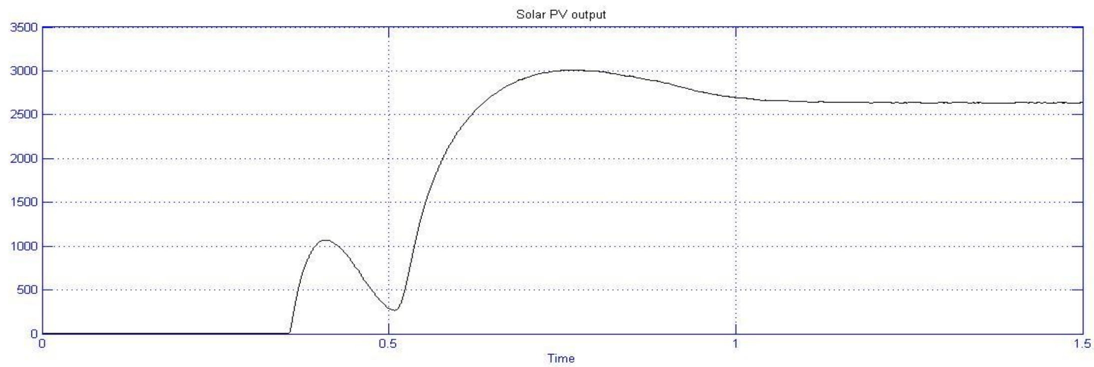

Fig. 10. SIMULINK OUTPUT of the solar PV Panel for Insolation -1000W/m^2

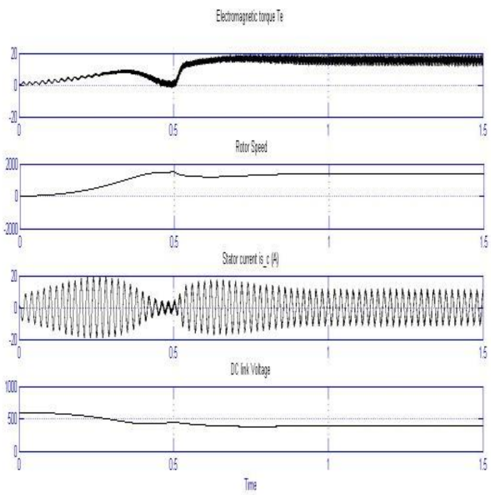

Fig. 11. Conventional Induction motor based on a single stage solar PV energy conversion system for solar PV Insolation -1000.

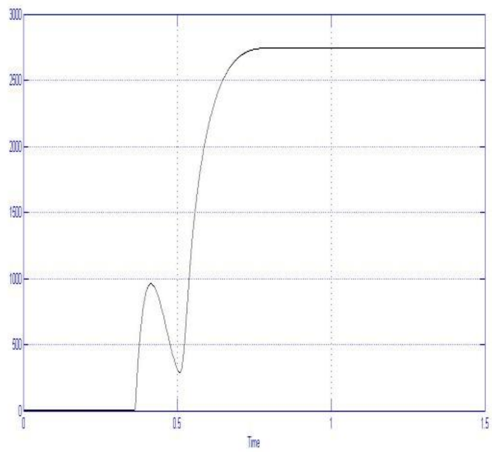

Fig. 12. SIMULINK OUTPUT of the solar PV Panel for Insolation -800.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 12, December 2019

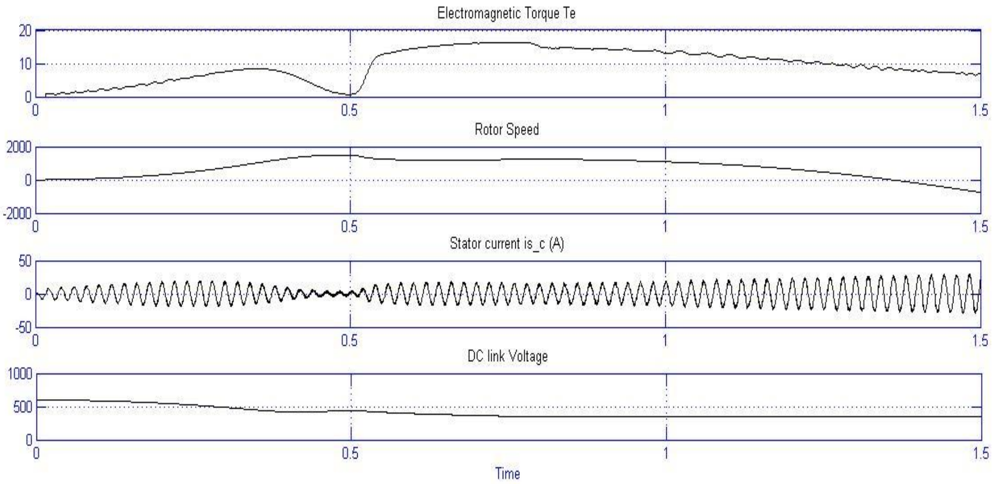

Fig. 13 SIMULINK OUTPUT of the Conventional Induction motor based on a single stage solar PV energy conversion system for solar PV Insolation -800.

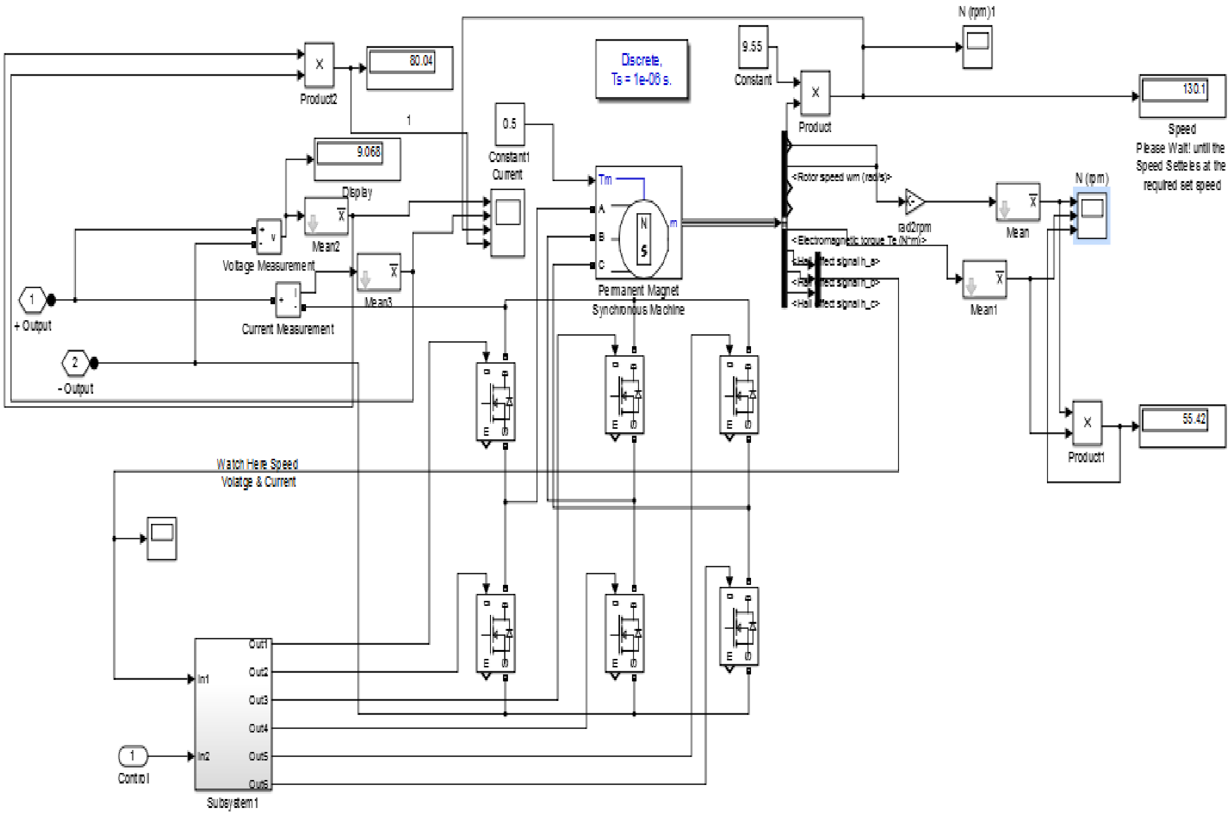

Fig. 14 SIMULINK model of the Conventional BLDC motor based on a single stage solar PV energy conversion system.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 12, December 2019

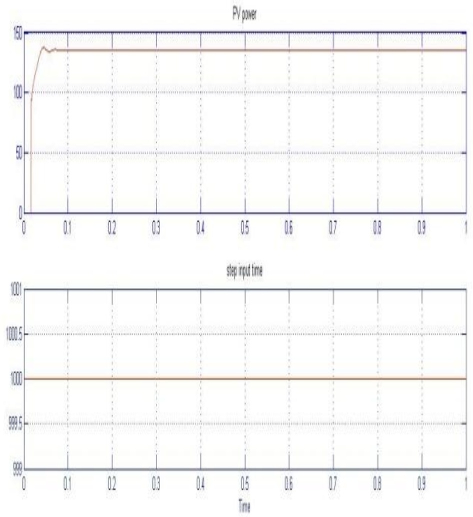

Fig.15. O/P Power of Solar PV Array that drives the BLDC Motor - Insolation - 1000

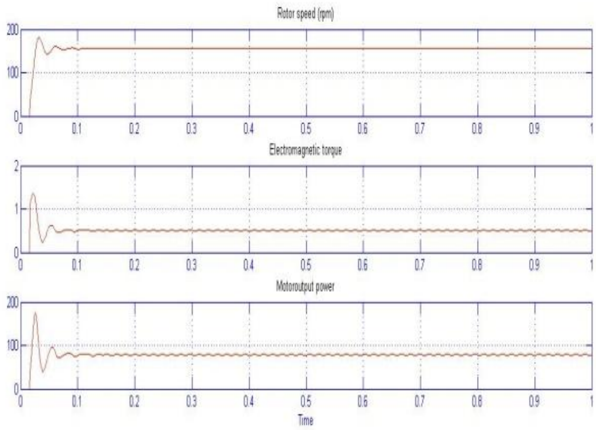

Fig. 16 SIMULINK OUTPUT of the Conventional BLDC motor based on a single stage solar PV energy conversion system for solar PV Insolation -1000.

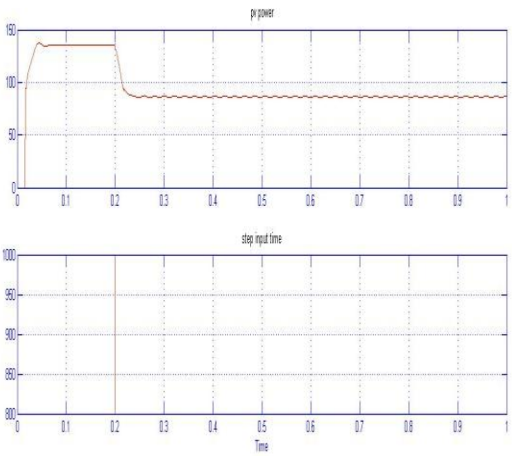

Fig.17. O/P Power of Solar PV Array that drives the BLDC Motor - Insolation - 800

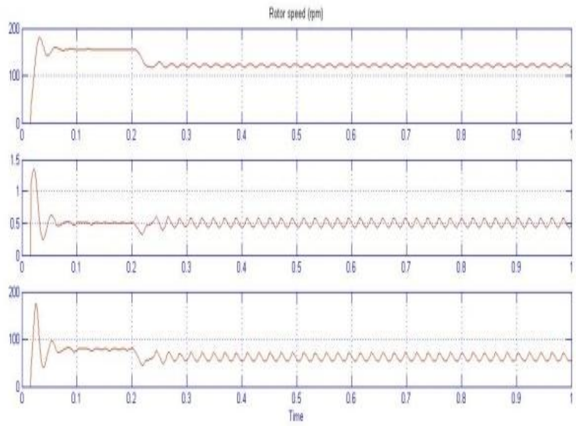

Fig 18. SIMULINK OUTPUT of the Conventional BLDC motor based on a single stage solar PV energy conversion system for solar PV Insolation -800.

VI. COMPARATIVE STUDY ANALYSIS

The SIMULINK model designed for the proposed motor system of both BLDC and Induction motor is simulated and the results are tabulated and further comparative study analysis is done.The Experimental results are observed by

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 12, December 2019

varying the Insolation of the solar input panel rated at 1000 and 800.The Solar panel o/p which is fed as i/p to the electric motor is noted and on simulating the Speed ,Torque and torque ripple at the motor end is noted .

Table:6.1 Experimental Results - Insolation – 1000 W/m^2

Insolation	Motors	Parameters					
		Solar PV o/p (W)	Speed (RPM)	Torque(NM)	Torque Ripple	Power(W)	Effficiency (η)
1000	Induction	2638	1450	15	0.5	2355	89.2
	BLDC	2364	1355	15	0.5	2334	89.9
800	Induction	2742	1359	14	0.5	1972.8	71.9
	BLDC	1926	1190	14	0.5	1743	90.3

VII. CONCLUSIONS

A comparison of the solar powered three phase Induction motor and the BLDC motor has been made. Both the motors operate satisfactorily with the solar power. Incremental conductance method has been implemented. A sliding Mode controlled MPPT can been adopted in both the cases. The induction motor drive works smoothly within the rated speed of 1500 RPM. The ripple is comparatively less. Since the current drawn by the induction motor is sinusoidal the harmonic losses in the motor are minimal. However, the BLDC motor works better with higher speeds. The absence of brushes, the light weight magnets make the BLDC motor more attractive as the torque by weight ratio is more compared to the BLDC motor. The proposed methodologies have been validated in MATLAB SIMULINK environment. The proposed techniques may, in future be developed using micro controllers as well as VLSI based FPGA processors. When realised in embedded systems the cost of the control scheme will come down and the proposed method will be well received by the industry.

REFERENCES

[1] Samimi et al., 1997. J. Samimi, E.Asl Soleimani, M.S. ZabihiOptimal Sizing of Photovoltaic Systems in Varied Climates. Solar Energy. J., 52 (1997), pp. 97-107.

[2] Hernández, J & Vidal, P & Almonacid, G. (1998). Photovoltaic in grid-connected buildings. Sizing and economic analysis. Renewable Energy. 15. 562-565. 10.1016/S0960-1481(98)00225-0.

[3] Ito, Masakazu & Kato, Kazuhiko & Sugihara, Hiroyuki & Kichimi, Tetsuo & Song, Jinsoo & Kurokawa, Kosuke. (2003). A preliminary study on potential for very large-scale photovoltaic power generation (VLS-PV) system in the Gobi desert from economic and environmental viewpoints. Solar Energy Materials and Solar Cells. 75. 507-517. 10.1016/S0927-0248(02)00198-8.

[4] Arvizu, Dan & Balaya, Palani & F. Cabeza, Luisa & Hollands, Kenneth & Jäger-Waldau, Arnulf & Kondo, Michio & Konseibo, Charles & Meleshko, Valentin & Stein, Wesley & Tamaura, Yutaka & Xu, Honghua & Zilles, Roberto & ABERLE, Armin & Athienitis, Andreas & Cowlin, Shannon & Gwinner, Don & Heath, Garvin & Huld, Thomas & James, Ted & Weyers, Paul. (2012). Direct Solar Energy. See Ref.. 106. 333 - 400. 10.1017/CBO9781139151153.007.

[5] Reinhard Haas a, Christian Panzer a, Gustav Rescha, Mario Ragwitz b, Gemma Reecec, Anne Heldb, A historical review of promotion strategies for electricity from renewable energy sources in EU countries, Renewable and Sustainable Energy Reviews 15 (2011) 1003–1034

[6] Bansal, N.K & Goel, Sandeep, 2000. "Integration of photovoltaic technology in cafeteria building, at Indian Institute of Technology, New Delhi," Renewable Energy, Elsevier, vol. 19(1), pages 65-70.

[7] Xiangyang, GongaManoharKulkarni b Design optimization of a large scale rooftop photovoltaic system,Solar Energy,Volume 78, Issue 3, March 2005, Pages 362-374

[8] H. H. El-Tamaly and A. A. Elbaset Mohammed, "Performance and economic study of interconnected PV system with electric utility accompanied with battery storage," 2006 Eleventh International Middle East Power Systems Conference, El-Minia, 2006, pp. 328-333.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 12, December 2019

[9] El-Tamaly, Hassan Hussein & Mohammed, Adel A. Elbaset, 2006. "Impact of interconnection photovoltaic/wind system with utility on their reliability using a fuzzy scheme," Renewable Energy, Elsevier, vol. 31(15), pages 2475-2491.

[10] Rajan Kumar, Member, IEEE, and Bhim Singh, Fellow, IEEE "Single Stage Solar PV Fed Brushless DC Motor Driven Water Pump" IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, VOL. 5, NO. 3, SEPTEMBER 2017

[11] P. Choudhary, R. K. Srivatava and S. De, "Solar powered induction motor based water pumping system: A review of components, parameters and control methodologies," 2017 4th IEEE Uttar Pradesh Section International Conference on Electrical, Computer and Electronics (UPCON), Mathura, 2017, pp. 666-678.

[12] H. Kukde and A. S. Lilhare, "Solar powered brushless DC motor drive for water pumping system," 2017 International Conference on Power and Embedded Drive Control (ICPEDC), Chennai, 2017, pp. 405-409.

[13] J. L. Davies and M. Malengret, "Application of induction motor for solar water pumping," 3D Africon Conference. Africon '92 Proceedings (Cat. No.92CH3215), Ezulwini Valley, Swaziland, 1992, pp. 209-212.

[14] V. Rana, Y. K. Chauhan and M. A. Ansari, "A multilevel inverter fed induction motor driven water pumping system based on solar photovoltaic," 2016 7th India International Conference on Power Electronics (IICPE), Patiala, 2016, pp. 1-5.

[15] D. Nandini and J. J. Daniel, "Modelling of BLDC motor driven solar water pump with INC-MPPT in MATLAB," 2017 International Conference on Circuit ,Power and Computing Technologies (ICCPCT), Kollam, 2017, pp. 1-7.

[16] R. Kumar and B. Singh, "BLDC motor driven solar PV array fed water pumping system employing zeta converter," 2014 IEEE 6th India International Conference on Power Electronics (IICPE), Kurukshetra, 2014, pp. 1-6.

[17] N. B. Yousuf, K. M. Salim, R. Haider, M. R. Alam and F. B. Zia, "Development of a three phase induction motor controller for solar powered water pump," 2nd International Conference on the Developments in Renewable Energy Technology (ICDRET 2012), Dhaka, 2012, pp. 1-5.

[18] S. S. Dessouky, A. A. Elbaset, A. H. K. Alaboudy, H. A. Ibrahim and S. A. M. Abdelwahab, "Performance improvement of a PV-powered induction-motor-driven water pumping system," 2016 Eighteenth International Middle East Power Systems Conference (MEPCON), Cairo, 2016, pp. 373-379.

[19] Sharaf, A.M. & Elbakush, E & Altas, İsmail. (2018). A NOVEL DYNAMIC ERROR DRIVEN TRACKING CONTRLLER FOR PV POWERED PMDC MOTOR DRIVES,Research gate Publications https://www.researchgate.net/publication/228777344.

[20] A. Unni and Mini V.P, "An efficient solar powered induction motor drive system," 2015 International Conference on Control Communication & Computing India (ICCC), Trivandrum, 2015, pp.155-160.

[21] Vikas V. Kulkarni1 , Bhushan L. Sonawane2," A Solar-Powered Induction Motor with Maximum Power Point Tracking Implemented On a Low-Cost PIC-Microcontroller",International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (An ISO 3297: 2007 Certified Organization) Vol. 5, Issue 8, August 2016

[22] P.Abarnaa1 , Mrs.S.P.G.Bhavani2 ,"A Solar Powered PV Based Induction Motor Drive in Water Pumping System Using Flc" International Journal of Scientific & Engineering Research, Volume 5, Issue 4, April-2014 39 ISSN 2229-5518

[23] Kashyap, Mohan & Chanana, Saurabh & Arya, Jai & Associate, Professor & , Head. (2013). SOLAR POWERED PMDC MOTOR DRIVE. World Conference on Advances in Communication & Control Systems, At DIT, Dehradun.

[24] K. H. Hussein, I. Muta, T. Hoshino and M. Osakada, "Maximum photovoltaic power tracking: an algorithm for rapidly changing atmospheric conditions," in IEE Proceedings - Generation, Transmission and Distribution, vol. 142, no. 1, pp. 59-64, Jan. 1995. doi: 10.1049/ip-gtd:19951577.

[25] A.Ravi , S.Murugan, J. Daniel Sathiyaraj, R.Aandal. "A Fuzzy Logic Controlled Solar Power Generation with Integrated Maximum Power Point Tracking using Multi-level inverter" International Journal of Applied Engineering Research. 10 (14), 2315-2326.

[26] Ravi A., P.S. Manohar "Closed loop control of Diode Clamped Multilevel Inverter with Integrated Maximum Power Point Tracking for Grid Connected Photovoltaic Application"PRZEGLĄD ELEKTROTECHNICZNY, NR 10/2013230-236.

[27] S. Kingson Solomon, A. Ravi , V. Vignesh Arumugam , J. Jasper Gnana Chandran "A Novel and Advanced Interleaved Power Converter for a Three Phase Standalone Inverter Compensated With STATCOM Using ANN" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering. Vol. 4, Issue 2, 2015.