Design and Control of Autonomous Wind Solar System with DFIG Feeding 3-Phase 4-Wire Loads

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Abstract **This paper proposed an autonomous wind-solar hybrid energy system feeding 3-phase 4-wire loads. The wind energy block consisting of a double fed induction generator (DFIG) is equipped with maximum power point tracking (MPPT) algorithm. The control of DFIG consists of two converters namely rotor side converter (RSC) and load side converter (LSC) connected back to back at DC link. The MPPT operation requires speed control, which is realized using field oriented control through RSC. The rotor position required for vector control, is estimated with model reference and adaptive system (MRAS) algorithm. The voltage and frequency control is realized through LSC. The solar photovoltaic (PV) power is extracted using a DC-DC boost converter to the common DC link. The DCDC converter is also equipped with MPPT algorithm to extract maximum power from the incident irradiance. The system is modeled in MATLAB and its performance is presented at conditions e.g. unbalanced nonlinear load, varying wind speeds and solar irradiation.**

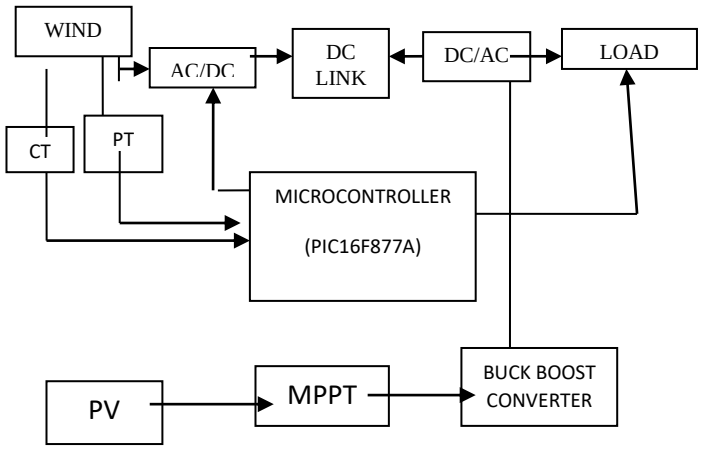
Keywords- PIC C COMPILER,EMBEDDED C for CONTROLLER CODING.

I. INTRODUCTION

Electricity is one of the most important gifts that science has given to mankind and it is difficult to imagine the world without it. However, large portion of global population does not have access to quality and reliable power. Though many of the remote locations have been declared electrified, however, they don't get power for more than few hours because of planned and unplanned outages. Planned outages are carried out by distribution companies due to their commercial interests. Unplanned outages occur due to environmental and man-made reasons e.g. overload, snapping and short circuit of conductor etc. Even if power is available, it is found that the voltage is low and has very high degree of unbalance. Distributed generation (DG) utilizing locally available renewable energy (RE) sources e.g. wind, solar, biomass, small hydro, can help these remote locations to attain self reliance in energy combined with quality and dependable power.

Wind and solar energies are the most important RE sources talked now a days. The wind power is already supplying noticeable share of energy of many countries. In India, A wind-solar hybrid system is moderately reported in the literature. Generators used for low power WES, are squirrel cage induction generator (SCIG) and permanent magnet generator (PMSG). The configuration using SCIG, requires full rated converters at machine as well load end [4-5]. With PMSG, full rated converters are required at machine as well load as side [6] or rectifier cum DC-DC converter at machine end and full rated converter at load end. These schemes incur more losses in addition to high cost of converters. Doubly fed induction generator (DFIG) is the most common machine used for commercial wind power generation. It has two voltage source converters namely rotor side converter (RSC) and load side converter (LSC). A hybrid of the DFIG in autonomous application can be achieved by connecting the output of SPVS through DC-DC converter at common bus or AC through an inverter. The former scheme is preferred for autonomous applications as it requires lower numbers of switches, filtering element and current sensors as compared to AC connection. Moreover, in case of connection of solar output at DC bus, the kVA rating of LSC is also lower. As a result of it, the DC bus hybrid is simple control as well as cost effective.

2. METHODOLOGY:



This proposed block diagram consists of following blocks

- Wind
- PV
- AC to DC converter
- DC to AC converter
- DC Link
- MPPT
- Buck Boost converter
- Microcontroller
- CT,PT

A. AC TO DC CONVERTER

Electric power is transported on wires either as a direct current (DC) flowing in one direction at a non-oscillating *constant* voltage, or as an alternating current (AC)

flowing backwards and forwards due to an oscillating voltage. AC is the dominant method of transporting power because it offers several advantages over DC, including lower distribution costs and simple way of converting between voltage levels.
Converters steer an alternating current, as its voltage also alternates, into reactive impedance elements, such as inductors (L) and capacitors (C), where it is stored and integrated. flyback converter differs from a forward converter in that its operation depends upon energy stored in the airgap of the transformer in the circuit. The simplest AC/DC converters comprise of a transformer following the input filtering, which then passes onto a rectifier to produce DC.

B .*DC TO AC CONVERTER*
Inverters can also be used with transformers to change a certain **DC** input voltage into a completely different **AC** output voltage (either higher or lower) but the output power must always be less than the input power: it follows from the conservation of energy that an **inverter** and transformer can't give out more power. Electronic inverters can be used to produce this kind of smoothly varying AC output from a DC input. They use electronic components called inductors and capacitors to make the output current rise and fall more gradually than the abrupt, on/off-switching square wave output you get with a basic inverter.

DC TO DC CONVERTER
SEPIC CONVERTER:
In high voltage applications, higher voltage rated power semiconductors are used. In order to reduce the volume and weight of the conductors, soft switching techniques such as ZCS and ZVS are necessary. The soft switching operations is increases the system efficiency. Efficient power conversion can be achieved by switched mode RF inverters like class E inverter. Class E inverter is commonly used in communication system and the biotelemetry instruments. The SEPIC (Single Ended Primary Inductance Converter) converter has low input current ripple. SEPIC is often used when the desired output voltage can be higher or lower than the input voltage[1].

WIND TURBINE:
Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity. The terms wind energy or wind power describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity.

PHOTOVOLTAIC CELL:
When semiconductor materials are exposed to light, the some of the photons of light ray are absorbed by the semiconductor crystal which causes a significant number of free electrons in the crystal. This is the basic reason for producing electricity due to photovoltaic effect. **Photovoltaic cell** is the basic unit of the system where the photovoltaic effect is utilised to produce electricity from light energy. Silicon is the most widely used semiconductor material for constructing the photovoltaic cell. As the negative charge (light generated electrons) is trapped in one side and positive charge (light generated holes) is trapped in opposite side of a cell, there will be a potential difference between these two sides of the cell. This potential difference is typically 0.5 V. This is how a **photovoltaic cells** or **solar cells** produce potential difference.
MPPT:
Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that “physically moves” the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Additional power harvested from the modules is then made available as increased battery charge current. When a conventional controller is charging a discharged battery, it simply connects the modules directly to the battery. This forces the modules to operate at battery voltage, typically not the ideal operating voltage at which the modules are able to produce their maximum available power.

BUCK BOOST CONVERTER:
The buck boost converter is a DC to DC converter. The output voltage of the DC to DC converter is less than or greater than the input voltage. The output voltage of the magnitude depends on the duty cycle. These converters are also known as the step up and step down transformers and these names are coming from the analogous step up and step down transformer. The input voltages are step up/down to some level of more than or less than the input voltage. By using the low conversion energy, the input power is equal to the output power.
It may be more or less than equal to the input voltage magnitude. There are two types of converters in the buck boost converter that are buck converter and the other one is boost converter. These converters can produce the range of output voltage than the input voltage.

MICROCONTROLLER:
In the microcontroller and the switching signal needed for the converter is produced. The esigned algorithm represents an integrated application of the change and supervises the algorithm and the current-controlled MPPT algorithms. It controls and monitor the wind and solar voltage and current through the ct and pt circuit and get the load parameter also.

PIC CONTROLLER
PIC is a family of modified Harvard architecture microcontrollers made by Microchip Technology, derived from the PIC1650 originally developed by General Instrument's Microelectronics Division. The name PIC initially referred to "Peripheral Interface Controller" now it is "PIC" only.
PICs are popular with both industrial developers and hobbyists alike due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, and serial programming (and re-programming with flash memory) capability.

Pulse-width Modulation?

Pulse Width Modulation (PWM) is a fancy term for describing a type of digital signal. Pulse width modulation is used in a variety of applications including sophisticated control circuitry. A common way we use them here at SparkFun is to control dimming of RGB LEDs or to control the direction of a servo motor. We can accomplish a range of results in both applications because pulse width modulation allows us to vary how much time the signal is high in an analog fashion. While the signal can only be high (usually 5V) or low (ground) at any time, we can change the proportion of time the signal is high compared to when it is low over a consistent time interval.

INTRODUCTION

The original PIC was built to be used with General Instrument's new CP1600 16-bit CPU. While generally a good CPU, the CP1600 had poor I/O performance, and the 8-bit PIC was developed in 1975 to improve performance of the overall system by offloading I/O tasks from the CPU. The PIC used simple microcode stored in ROM to perform its tasks, and although the term was not used at the time, it shares some common features with RISC designs.

2.MATLAB/ SIMULATION

SOFTWARE SIMULATOR

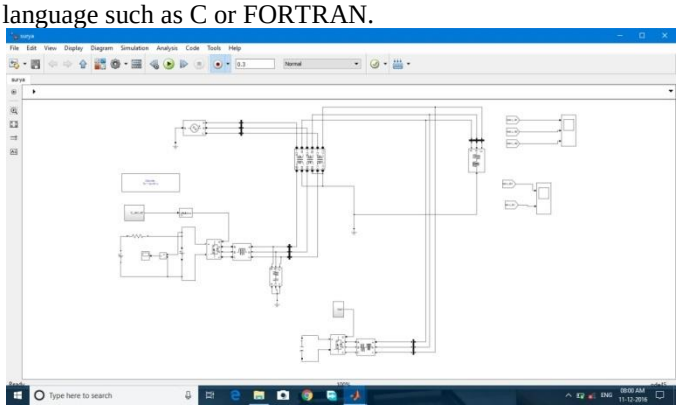
INTRODUCTION

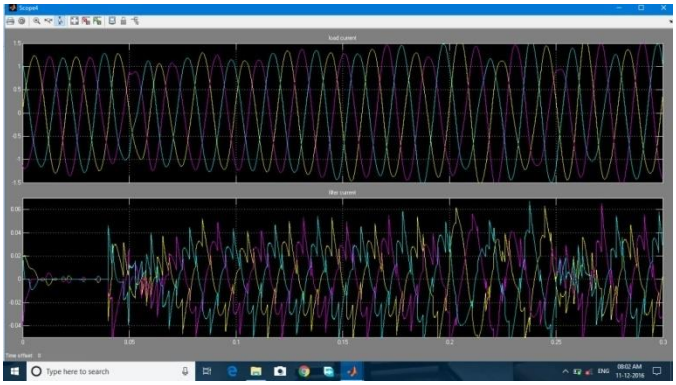
MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.

Typical uses include:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including Graphical User Interface
- building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.





VI. CONCLUSIONS

Wind and solar energies are free of cost, however, unpredictable with high degree of variance. With the help of energy storage and intelligent PE control, these RE sources can be made customer friendly. This work presents theoretical and experimental validation of autonomous wind solar hybrid system consisting of wind generator with DFIG and solar PV array. Both solar and wind energy blocks are equipped with MPPT logic to extract the maximum energy. It is also found that the power quality is within acceptable limit. The high cost of the battery and its limited life, may push up the cost of energy higher. However, in line with the solar module, battery prices have started falling driven by demand from electric vehicles, large storage stations combined with technological development. This increases the relevance of the system for DG system at remote locations so as the residents fulfill their energy requirement without dependency to external grid.

APPENDICES

A. Parameters of DFIG Make- MacFarlane Engineering Co Ltd, 3.7 kW, 4 Pole, 400 V, 50 Hz, Y-connected, Rs=1.32 Ω, Lls=6.832 mH, Rr =1.708 Ω, Llr=6.832 mH, Lm=219 mH, Inertia=0.1878 kg-m2. B. Parameters of DC Machine 5 kW, 230 V, Irated=21.8 A,Ra=1.3 Ω, Rf=220 Ω, La=7.2 mH, Lf=7.5 H, Kφ=1.3314 C. Gains of PI Controllers Speed controller: Kpr = 12, Kir = 45. Voltage controller: Kpv = 0.4, Kiv = 2

REFERENCES

[1] http://www.gwec.net/global-figures/graphs/
[2] http://mnre.gov.in/mission-and-vision-2/achievements/
[3] R. Bannejee, “Comparison of options for distributed generation in India,” Energy Policy, vol. 34, pp. 101–111, 2006.
[4] L. Whei-Min, H. Chih-Ming and C. Chiung-Hsing, “Neural-Network- Based MPPT Control of a Stand-Alone Hybrid Power Generation System,” IEEE Trans. Power Elect., vol. 26, pp. 3571-3581, Dec 2011.
[5] M. Rezkallah, S. Sharma, A. Chandra and B. Singh, "Implementation and control of small-scale hybrid standalone power generation system employing wind and solar energy," 2016 IEEE Industry Applications Society Annual Meeting, Portland, OR, 2016.
[6] X. Yang, X. Gong and W. Qiao, "Mechanical sensorless maximum power tracking control for direct-drive PMSG wind turbines," 2010 IEEE Energy Conversion Congress and Exposition, Atlanta, GA, 2010.

[7] C. N. Bhende, S. Mishra and S.G. Mall,"Permanent Magnet Synchronous Generator-Based Standalone Wind Energy Supply System" IEEE Transactions on Sustainable Energy, vol. 2, no. 4, October 2011.
[8] S.K. Tiwari, Bhim Singh and P.K. Goel, "Design and control of wind- solar energy system with DFIG feeding a 3-phase 4-wire network", 2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (PEICES), 4-6 July 2016.
[9] A. Hamadi, S. Rahmani, K. Addoweesh and K. Al-Haddad, "A modeling and control of DFIG wind and PV solar energy source generation feeding four wire isolated load" 39th Annual Conference of the IEEE Industrial Electronics Society, IECON 2013, 10-13 Nov, 2013 pp. 7778 – 7783
[10] M. R. A. Hamadi, A. Chandra and B. Singh, "Hybrid AC-DC standalone system based on PV array and wind turbine," IECON 2014 - 40th Annual Conf. of IEEE Industrial Elect. Society, Dallas, TX, 2014, pp. 5533-5539.
[11] M. Pattnaik and D. Kastha,"Comparison of MRAS based speed estimation methods for a stand alone Doubly Fed Induction Generator", Inter. Conf. on Energy, Automation, and Signal (ICEAS), Dec. 2011.
[12] H. M. el-helw and S. B. Tennakoon, "Vector Control of a Doubly Fed Induction Generator for Standalone Wind Energy Application," 2008 Wind Power to Grid - EPE Wind Energy Chapter 1st Seminar, Delft, 2008.
[13] IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems - Redline," IEEE Std 519-2014 (Revision of IEEE Std 519-1992), pp.1-213, June 11 2014.
[14] S. Heier, Grid Integration of Wind Energy Conversion Systems. Hoboken,NJ: Wiley, 1998.
[15] Xiong Liu, Peng Wang and Poh Chiang Loh, "A Hybrid AC/DC Microgrid and Its Coordination Control," IEEE Transactions on Smart Grid, vol. 2, No. 3, pp. 278 – 286, June 2011.
[16] N. Mohan, T. M. Undeland, and W. P. Robbins, Power Electronics: Converters, Applications, and Design, 3rd ed. New Delhi, Wiley, 2009.
[17] P. K. Goel, B. Singh, S. S. Murthy and N. Kishore, "Modeling and control of autonomous Wind Energy Conversion System with Doubly Fed Induction Generator," 2010 Joint Inter. Conf. on Power Electronics, Drives and Energy Systems & 2010 Power India, New Delhi, 2010.
[18] B. Singh, C. Jain and Sagar Goel, "ILST Control Algorithm of Single- Stage Dual Purpose Grid Connected Solar PV System," IEEE Transaction on Industrial Electronics, vol. 29, No.10, October 2014.