

Advanced Control Strategy of Renewable Energy Conversion System for Power Quality Improvement of Hybrid Generation System

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ABSTRACT: This paper proposed an intelligent extraction of optimum power and its dispatch for power quality improvement using adaptive fuzzy logic algorithm from a grid tied hybrid generation system. The dc link control strategy is based on the adaptive fuzzy logic controller, which improves the dc link voltage error, its rate of change and error in the direct axis current of the inverter. For wind energy conversion system, Maximum Power Point Tracking (MPPT) control is implemented under variable speed. The extensive simulation results have carried out in MATLAB/SIMULINK. From the result it has shown that hybrid of renewable energy with adaptive fuzzy logic achieve superior capability of mitigating the effects of voltage sag/swell, suppressing the load current harmonics and also reduces high frequency oscillation in the wind extracted power. The dynamic performances of both adaptive fuzzy proportional – derivative and integral (PD+I) controller controls the inverter current and also reduces the probability of failure in the converter switches and other components.

I. INTRODUCTION

With rapid economic growth, the demand for energy is increasing energy is by far the largest industry in the world. Presently, the known alternatives to energy production from fossil fuels are renewable energy. The renewable energy is the energy source that are natural and continuously refilled either at the same rate or faster than the rate at which they are being used up by humans more or less indefinitely such as the sun, wind etc. The green energy, alternative energy and sustainable energy are the other synonyms occasionally used to describe the renewable energy that is converted into electricity, heat or mechanical power for use in home or in industries by clean, harmless and non polluting methods.

Formal definition of renewable energy sources varies from country to country, but there is broad agreement that wind energy, photovoltaic, and solar thermal energy is considered to be renewable.

Power Quality is any abnormal behaviour on a power system arising in the form of voltage and/or current, which adversely affects the normal operation of electrical or electronic equipment . It is defined in another way; Power quality is any deviation of the voltage or current waveform from its normal sinusoidal wave shape. These disturbance include, but are not limited to sag, under voltage, interruption, swell, over voltage, transients, voltage flicker and any other distortion to the sinusoidal waveform. Occurrence of one or more of such disturbance is called a power quality event.

The power supply system can control only the voltage quality. It has no control over the currents that particular load might draw. There is always a close relationship between voltage and current in any practical power system.

In this work, a adaptive fuzzy logic controller has been designed for an auto-adjustable DC-DC converter. The output characteristic was analyzed, whenever operating-point changes or parameters disturbed. The controller structure incorporates attractive features such as good performance and simplicity.

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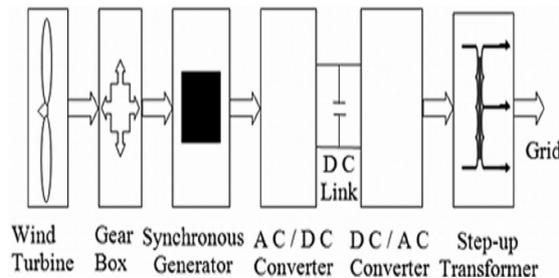
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Due to, single-ended primary-inductor converter (SEPIC) and its output gain flexibility acts as a Buck-Boost DC/DC converter, where it changes its output voltage according to its duty cycle. SEPIC converter is more conventional than buck-boost converter, which has a non-inverted output and it uses a series capacitor to isolate input from output [1]. Due to input current series switching the buck and buck-boost converters lose half of their input power; for that reason, the two types of converters should be excluded from maximum power applications. The boost converter which may not achieve maximum power transfer operation because it has continuous input current, but the output voltage is always larger than the input.

II. WIND ENERGY CONVERSION SYSTEM

A wind energy conversion system converts wind energy into some form of electrical energy. In particular, medium and large scale WECS are designed to operate in parallel with a public or local ac grid. This is known as a grid connected system. A small system, isolated from a grid, feeding only to a local system. A general block diagram of a grid connected WECS is shown. The turbine shaft speed is stepped up with the help of gears, with a fixed gear pitch control. This block acts as a drive for the generator. Use of variable gear ratio has been considered and was found to add more problems than benefits. Hence dc, synchronous generator are used for mechanical to electrical power conversion depending on the design of the system. The interface conditions the generated power to grid quality power. It may consist of a power electronic converter, transformer and filter, etc. The control unit operates and supervises the interaction among various blocks. It calculates the reference voltage and frequency signals from the grid and gets wind speed, wind direction, wind turbine speed signals, etc., processes them and accordingly controls various block for optimal energy balance.



III. MPPT IN WIND

A symbolic wind turbine Power-Speed characteristic is plotted. Depending on wind velocity, four different operating regions are existed. Regions 1 and 4 are impractical because no constant power output can be expected before the cut in (C_{in}) and after cut off (C_{off}) speed; hence, for grid connection the wind turbine operation during this period is not recommended. In the meantime, the second region between $N_C - W_{in}$ and N_{Rated} is the ideal zone for power generation via Wind Energy Conversion System (WECS). Moreover, Maximum Power Point Tracking (MPPT) operation is possible only when wind turbine has operated in this region. Since the maximum power limit has been already reached by the third region, ($N_{Rated} - N_C - W_{of}$), the control over mechanical output power becomes more essential. Thus, the above discussion deduce that region 2 is the optimized zone to implement maximum power point tracking in WECS.

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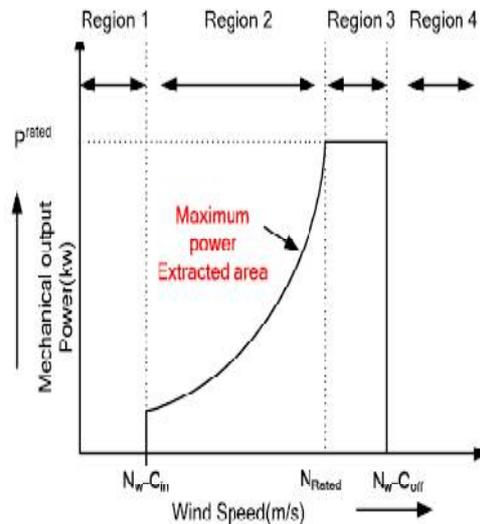


Fig. 1. Different operating regions of wind turbine based on wind velocity [7].

MPPT techniques in WECS

MPPT techniques in WECS can be categorized into the Direct Power Control (DPC) and Indirect Power Control (IPC) methods. The execution procedure and their control technique adopted to reach MPP.

IV. PV SYSTEM

The Photovoltaic Effect is the electrical potential formed amidst two different materials when their common junction is illuminated with radiation of photons. The photovoltaic cell, thus, converts light directly into electricity. Single PV cells (also known as “solar cell”) are connected electrically to form PV modules, Which are the building block of PV systems. The module is the smallest PV unit that can be used to generate substantial amounts of electricity, PV module are manufactured with varying electrical output ranging from a few watts to more than 100 watts power of direct current (DC) electricity. The modules can be connected into PV array for powering a wide variety of electrical equipment.

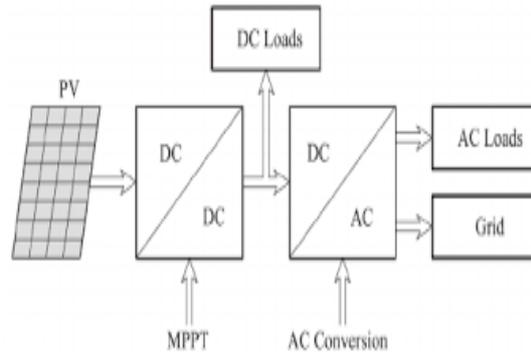
Two primary types of Photo Voltaic technologies available commercially are thin film and crystalline silicon. In crystalline-silicon technologies, individual PV cells are cut from large single crystals or from ingots of crystalline silicon. In thin film Photo Voltaic technologies, the Photo Voltaic material is deposited on thin metal or glass that mechanically supports the cell or module. Thin-film-based modules are produced in sheets that are sized for specified electrical outputs. In addition to Photo Voltaic modules, the components needed to complete a Photo Voltaic system may include a battery charge controller, batteries, power control unit (for alternating-current loads) or an inverter, safety disconnects and fuses, a grounding circuit and wiring.

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The output voltage of solar system is fluctuating so the sepic converter (dc-dc converter) is used in this paper, which regulate and boost up the output voltage. The adaptive fuzzy logic controller is used to give duty cycle to sepic converter to extract maximum power point.

V. ADAPTIVE FUZZY LOGIC CONTROL

The performance-robustness adjustment is not usually taken into account in normal FLC tuning. Normally hand-tuned FLC happened to be robust because they do not exploit to a full extent the plant characteristics which is not continues, so it's performance is far from being stringent at time-optimal. In normal fuzzy logic controller much simpler global description may exist, being hidden by too detailed local descriptions as in most modelling situations, the compromise between readability and accuracy may be present. So the Adaptive Fuzzy Logic method is preferred here which is used as the speed controller in the proposed system, which improves the transient response of the system and minimizes the rise time. The present practical successes of fuzzy control are mainly due to its high-speed implementation, low developing cost and capability of incorporating linguistic information from human experts. The successful tracking is performed by adaptive fuzzy controllers without using any linguistic information.

Adaptive Fuzzy Logic Controller have the advantages of working with imprecise inputs , not needing an accurate mathematical model, and handling nonlinearity.

Adaptive Fuzzy logic control generally consists of three stages:

- Fuzzification,
- Rule base table lookup, and
- Defuzzification

During fuzzification, numerical input variables are changed into linguistic variables based on a membership function .Here, five fuzzy levels are used: negative big(NB), negative small(NS), zero(ZE), positive small(PS), and positive big(PB). The membership function is sometimes made less symmetric to give more importance to specific fuzzy levels. The input to a Maximum Power Point Tracking adaptive fuzzy logic controller are usually an error E and a change in error E. The user has the flexibility of choosing how to compute E and E. Since dp/dv vanishes at the MPP, uses the approximation

$$\frac{E(n)-P(n)-P(n-1)}{V(n)-V(n-1)} \quad \Delta$$

And

$$E(n)= E(n)-E(n-1) \Delta$$

Once E and ΔE are calculated and converted to the linguistic variables, the Adaptive Fuzzy Logic controller output which is typically a change in duty ratio ΔD of the power converter, can be looked up in a rule base table.

The linguistic information variables assigned to ΔD for the different combination of E and ΔE is based on the power converter being used and also on the knowledge of the user.

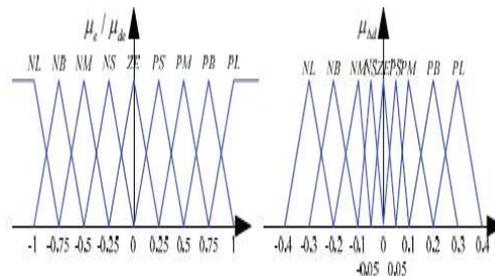
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In the defuzzification stage, the fuzzy logic controller output is converted from a linguistic variable to a numerical variable still using a membership function. This gives an analog signal that will operate the power converter to the MPPT.



Membership function for input and output of fuzzy logic controller

MPPT adaptive fuzzy logic controllers have been shown to work well under changing atmospheric situations. However, their effectiveness depends on the knowledge of the user or control engineer in choosing the right error computation and coming up with the rule base table

Table 1. Fuzzy Rule Table

$de \setminus e$	NL	NB	NM	NS	ZE	PS	PM	PB	PL
NL	NL	NL	NL	NL	NL	NS	ZE	PS	PM
NB	NL	NL	NL	NB	NB	ZE	PS	PM	PM
NM	NL	NL	NB	NB	NM	PS	PS	PM	PB
NS	NL	NL	NB	NM	NS	PS	PM	PM	PB
ZO	NL	NB	NM	NS	ZE	PS	PM	PB	PL
PS	NB	NB	NM	NS	PS	PM	PM	PB	PL
PM	NB	NM	NS	NS	PM	PB	PB	PL	PL
PB	NM	NM	NS	ZE	PB	PB	PL	PL	PL
PL	NM	NS	ZE	PS	PL	PL	PL	PL	PL

VI. SEPIC CONVERTER

The single-ended primary-inductance converter (SEPIC), a DC-DC-converter topology is a modification of the basic Cuk and the Boost converter, It provides non inverted regulated output voltage from an input voltage that varies from above to below the output voltage. The buck-boost has discontinuous currents on both the input and output, which is difficult for power factor correction application. For that reason we can use this sepic converter. However, Buck-Boost and Cuk converter operation cause large amounts of electrical stress on the components, this can result in overheating or device failure. SEPIC converters solve both of these problems. SEPIC converter is superior to the other converters in terms of the input current purity, output noises and efficiency.

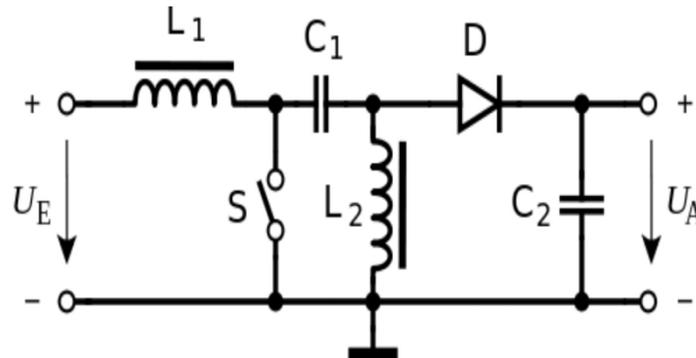
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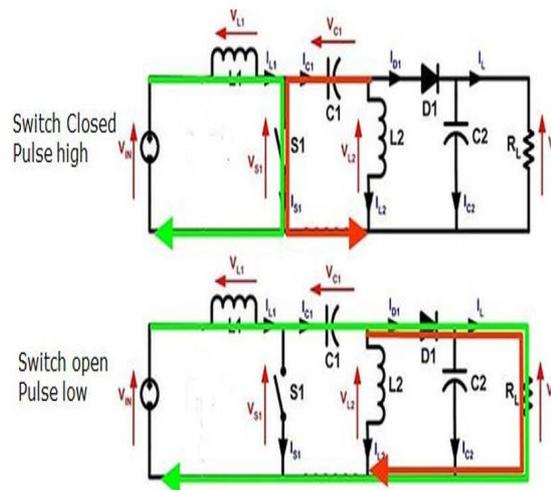
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Circuit diagram



Operation

For the Single-Ended Primary-Inductance Converter (SEPIC), when the pulse is high/the MOSFET is on, inductor 1 is charged by the input voltage and inductor 2 is charged by capacitor 1. The output is maintained by capacitor 2 when the diode is off. When the pulse is low/the MOSFET is off, the inductors output through the diode to the load and the capacitors are charged. If the percentage of time (duty cycle) is greater, then the pulse is low, and the output will be greater. When the inductors charge is larger, then their voltage will be greater. However, if the pulse is too long, the capacitors will not be able to charge and the converter will fail.



VII. HYBRID WIND SOLAR POWER SYSTEM

The block diagram representation of the wind/PV system for its grid integration is shown. The wind power system with uncontrolled rectifier with DC-DC converter is connected to a DC bus. Similarly the PV arrays are connected to DC bus via a DC-DC sepic converter.

The wind and photovoltaic generators are operated with maximum power tracking controller locally to obtain the maximum power extraction. For the analysis of the grid connected hybrid system, both Direct Current and Alternating Current loads are considered. The DC load is tied through a DC-DC sepic converter to the DC bus. In grid tied operation mode, the grid side inverter is responsible for constant DC bus voltage and introduces only active power to

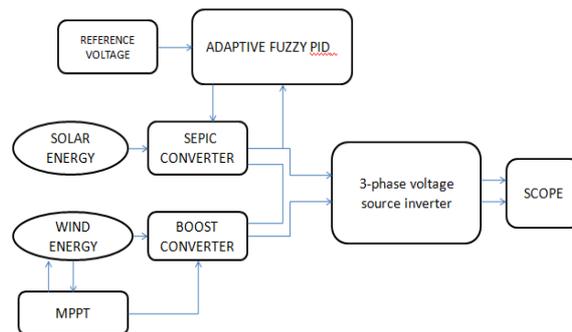
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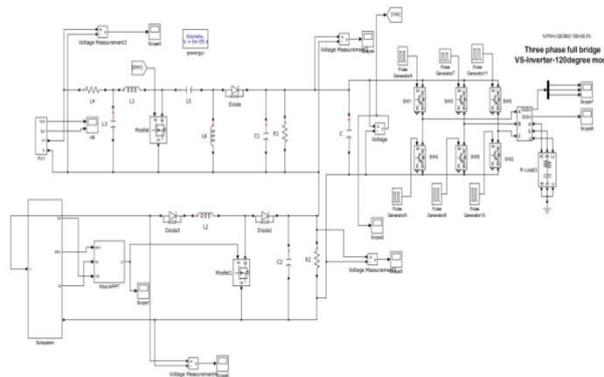
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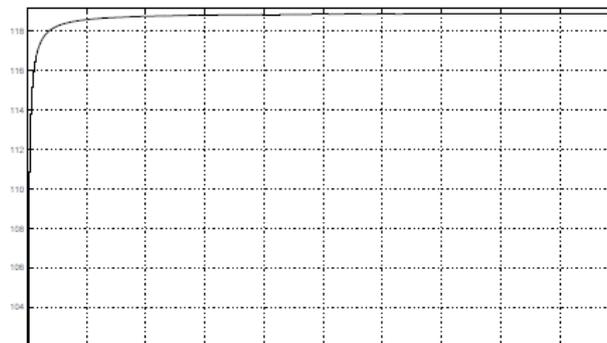
the grid with zero reactive power. The function of the inverter control strategy is to maintain the fixed DC bus voltage and to supply the total maximum power produced by the solar and wind to the grid.



VIII. SIMULATION DIAGRAM AND RESULTS



Solar Panel output



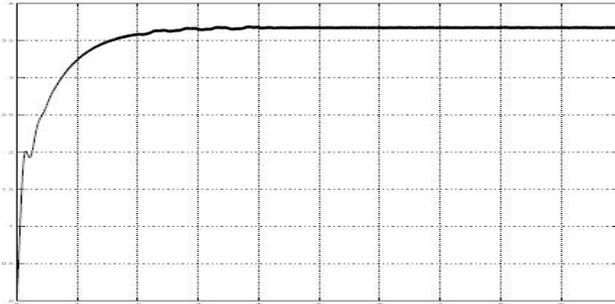
Wind system output

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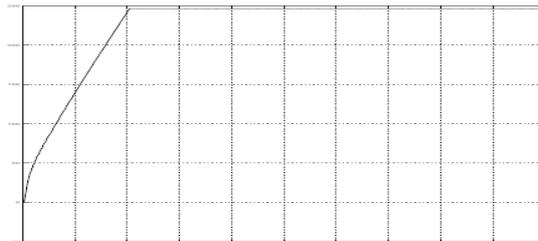
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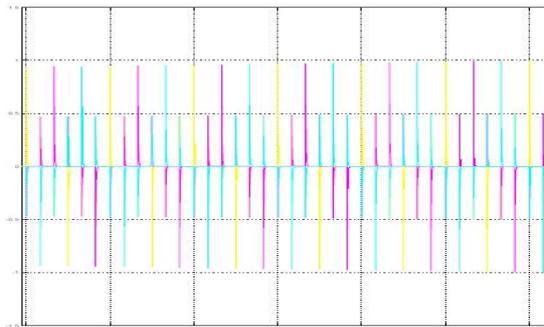
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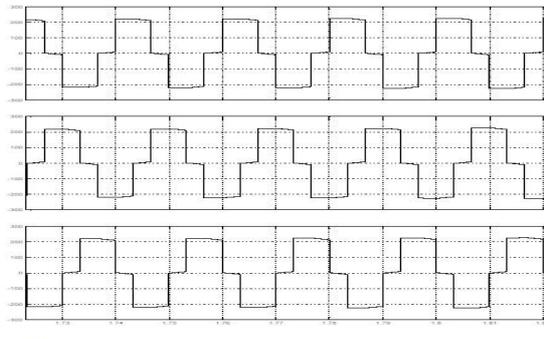
Overall output



Output current of the inverter



Output voltage of the inverter



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IX. CONCLUSION

This work emphasises to extract maximum power from concentration LCPV solar generator and optimum power from a direct driven wind power generator to provide necessary power to the local load and the grid. The power extractions are done intelligently using adaptive fuzzy logic control but wind power being the dominant contributor amongst the two, inject high frequency oscillations in the dc link power. Therefore extraction of power from the generator by the proposed method focuses to reduce active power and stabilise dc link voltage differs at the inverter output. This method uses intelligently the knowledge of transient power is not symmetrical at the dc link and the variation of load current to extract and dispatch maximum possible power with a better quality at the inverter output. Magnitude and frequency of the inverter output voltage is maintained at its desired nominal value without any voltage sags/swells as load changes. Adaptive Fuzzy PD+I control of the inverter proves to be the best amongst the modes of operation discussed in stabilising dc link voltage, improved grid support and improving THD of the inverter output voltage and current

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