COST EFFECTIVE CHARGE CONTROLLER FOR WIND BASED POWER GENERATION

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ABSTRACT: Wind-based power generation is being used in certain regions around the globe. The power which is generated using wind turbines is the function of speed of wind and wind turbine assembly. Wind turbine assembly is a constant factor and generated power from wind turbine varies directly as wind speed varies. This research paper proposes a cost effective microcontroller based charge controller that can control variable voltage coming out of wind turbine and either store it in battery or drive a load directly. The brief list of requirements for charge controller like type of battery, charge storage capacity and charging time are discussed and also steps to implement above mentioned requirements in microcontroller with certain assumptions to maintain domain boundary are analysed. The results are efficiently described using graphical and textual data comparison. This proposed cost effective solution will certainly help to maximize the power generation using wind turbine.

Key words: wind turbine, battery charge controller, buck convertor, battery charging, microcontroller.

INTRODUCTION

The price hike in fuel causing increased power generation cost and this is a good trigger for researchers and organizations to research in renewable energy resources like solar and wind sources. The beneficiaries would be people who are far away from power network and general people with substantial reduction in power utility bills.

All available renewable energy systems have some kind of deficiencies, out of these deficiencies the most important is prediction about availability of power, like in case of solar systems a sudden change in clouds above PV system can degrade the power production in the same way a sudden change in wind speed can enhance or reduce produced power. To compensate this uncertainty of availability of power certain energy storage devices like batteries are used (Borhan *et al.*, 2012 andKhalid and Savkin, 2009). By introducing energy storage mechanism user is not directly dependent on available power, it can utilize power stored in battery, but still batteries have certain capacity of charge storage and they can drive a certain load for a certain time period (T). This time period can also vary if battery is charged using intermittent power which is generated due to variable wind speed. So we must have to use a battery of suitable capacity to eliminate this power uncertainty issue, use of battery resolves availability of power issue but the time period,*T*, cannot be predicted if a constant load is being driven by battery (Okui and Yoshimoto, 2007).

Based on analysis discussed by (Schoenung and Hassenzahl 2003 and Borhan *et al.*, 2012) it was observed that lead acid batteries were best available option in terms of cost and performance for wind based applications.

The under investigation system parts are as follows:

- Variable speed permanent magnate synchronous generator (PMSG)
- Lead acid battery
- DC-DC converters
- Rectifiers
- Power supply
- Proposed Microcontroller based charge controller

The model of the system is as follows.

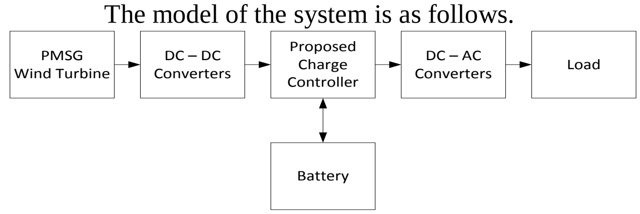

Fig. 1: System Diagram

MATERIALS AND METHODS

The microcontroller which is used in charge controller should have ADC module as different voltages like voltage coming out of wind turbine, battery voltage, voltage of buck converter etc. is to be gauged to adjust PWM to control the buck voltage or current which is fed to battery or to load using inverter.

V_{OUT} = Turbine Voltage
V_{BAT} = Battery Voltage
V_{CHARGE} = Buck Voltage
V_{LOAD} = Load Voltage
I_{CHARGE} = Buck Current
I_{OUT} = Turbine Current

I_{LOAD} = Load Current

The microcontroller should have digital output modules as it would generate certain outputs to control various items like, LED, Buzzer and PWM based gate drives.

Charge controller should monitor the terminal voltage of battery V_{BAT} and by applying different combinations of currentI_{CHARGE} and voltage V_{CHARGE} should make sure that battery is fully charged for most of time, the charging of battery should be performed in following four steps.

Constant Current Charge: In this mode constant current I_{MAX} is applied, due to this current, the voltage of each cell in battery rises up to a certain level.

Saturation Charge: In this mode constant voltage is applied, the charge transferred to cells decreases gradually.

Ready, No Charge: In this mode battery is disconnected as it is fully charged and no current or voltage is applied.

Maintenance Charge: Charge decreases in each cell due to absorption, guessing effects and leakage which causes decrease in voltage of each cell. To avoid this if no load is connected, a constant voltage is applied till the voltage of each cell rises to a particular level and then the applied voltage is disconnected.

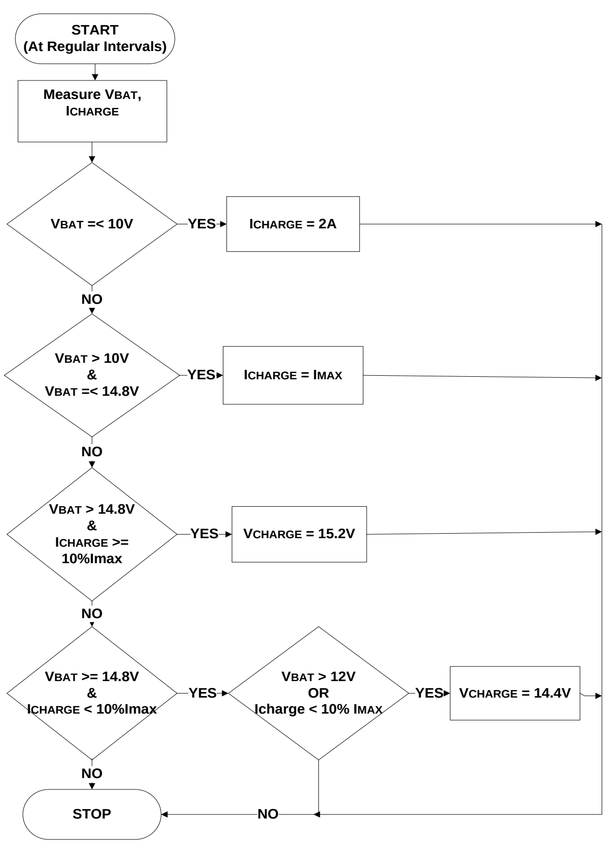

Fig. 2: Four Stage Charging Flow Chart

RESULTS AND DISCUSSION

As we discussed in the introduction that the power generated from wind source can be intermittent and would always vary with the speed of wind. However at different wind speeds wind turbine provides maximum available power at different points, these points must be tracked to have maximum power at different wind speeds (Valenciaga and Puleston, 2005 andMeenakshi *et al.*, 2006).

There are different algorithms devised to track maximum power point at the IV curve of wind turbine. Here we would use Perturbation and Observation (P&O) MPPT method discussed in (Glavin and Hurley, 2006). In this algorithm if perturbation causes an increase in power then that means this is not the maximum power point and the perturbation takes place in same direction but if perturbation cause a decrease in power then the perturbation take place in opposite direction. Perturbation is performed at regular intervals and MPPT is tracked according to the result of perturbation.

In multistage charging mechanism there should be careful selection of hysteresis window(Meiqin *et al.*, 2008).If this window is too small battery may oscillate between different charging modes and if this window is too large the battery may remain in a single charging mode for a long time which may cause overcharge or low charge which can result in poor charging or a permanent damage to the battery. This applies at all points where voltage may vary and certain decisions are to be taken by microcontroller on these changes.The hardware design shall feature a dumping load to restrict the wind turbine voltage within safe limits.The hardware design shall feature a hard-wired emergency ‘stop switch’ to engage the dumping load permanently to stall the turbine to halt

A wind based electric battery charging mechanism requires a variable speed Permanent magnet alternator turbine to capture, convert and store the wind energy into usable electric power. As discussed earlier a major technical constraint in the design of this system is the intractability of wind. The output power of the wind turbine is a second degree function of rotor radius and third degree of wind speed (Okui and Yoshimoto, 2007 and Borowy and Salameh, 1997).

The rotor remains constant. The variable wind speed may change the DC output of wind turbine, the DC output power of wind turbine can be very high and cannot directly charge the battery, as a remedy for this problem DC-DC buck converter is required.

Senario1:

$$P_{wind} > P_{Load} \rightarrow Buck_{ON}$$

Senario2:

$$P_{wind} < P_{Load} \rightarrow Buck_{Bypass}$$

Senario3:

$$P_{wind} < (P_{Load} \,\&\, V_{charge\max}) \rightarrow Buck_{OFF}$$

Microcontroller Interfacing: A Crystal of 20MHz drives microcontroller, 5V regulated power is provided by 78L05 voltage regulator circuit. There is auxiliary IO interfaces (LCD, LED, Keypad, and Buzzer) attached with microcontroller to provide bidirectional communication between charge controller and user.

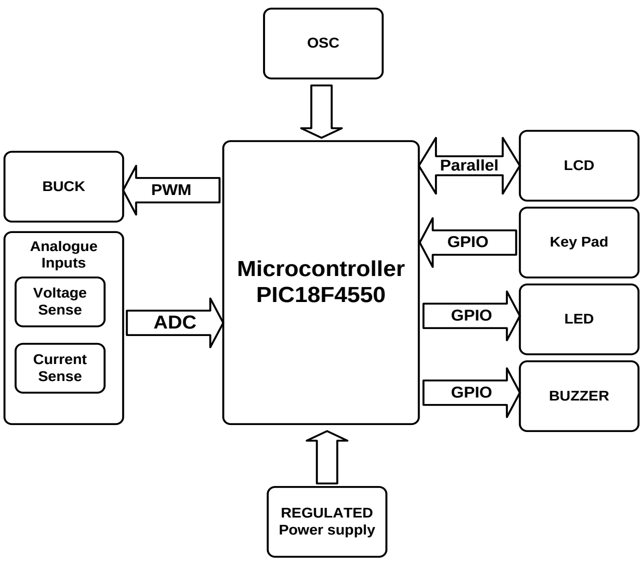

Fig. 3: Microcontroller Block Diagram

These interfaces are not a must requirement for this charge controller, whereas there are some analogue inputs in the form of sensed voltage and currents (VOUT, VBAT, VCHARGE, VLOAD, ICHARGE, IOUT, ILOAD) which are to be read on ADC channels, out of these certain analogue inputs certain inputs are to be read on higher ADC resolution and on priority as certain activities are to be performed in micro seconds resolution.

Tasks Performed In Microcontroller: The essential task of microcontroller for acting as 'charge controller' is explained in this section. The other optional communication interfaces for status updates are not listed.

Analogue to Digital Conversion: The selected microcontroller has 10 bit ADC module which is being used to convert analogue signals into 0-5V digital signal. Certain high priority analogue signals are read directly on microcontroller pins configured as analogue input whereas rest of low priority signals are being read on regular intervals using analogue MUX chip.

Buck Control: To control the 'buck converter', the V_{OUT} analogue signal is read at microcontroller input pin along with V_{LOAD}. If voltage coming out of wind turbine is sufficient enough and greater then load voltage and maximum voltage which can be applied to battery to charge it, then it must be downgraded. For this purpose the 'buck converter' is turned on.

If voltage coming out of wind turbine is less than load voltage and greater then minimum voltage required to charge the battery, then the 'buck converter' is bypassed as there is no need of DC-DC voltage conversion.If voltage coming out of wind turbine is less than load voltage and minimum voltage required to charge the battery then the 'buck converter' is turned off.

Buck PWM Generation: If 'buck converter' is on PWM signals are to be generated to control V_{CHARGE} and I_{CHARGE} so that the voltage is in accordance with volts required charging the battery or driving load.

Following state transition diagram explains the 'buck PWM' generation.

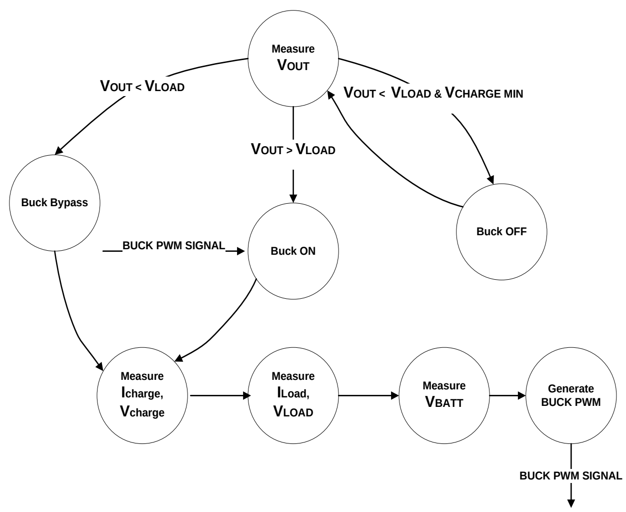

Fig. 4: State Transition Diagram

Charging Mode Selection: If 'buck converter' is on and voltage is available for battery, the 'charge controller' shall measure VBAT and will adjust VCHARGE and ICHARGE by using 'buck PWM' to select appropriate battery charging stage. As VBAT changes, VCHARGE and ICHARGE shall also be changed and battery charging stage will transit between 4 charging stages as discussed in functional requirements.

Following figure shows signals required for selecting charging mode.

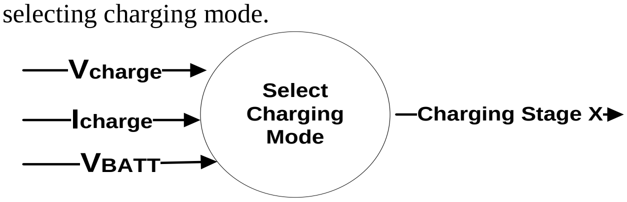

Figure 5. Battery Charging Mode Selection

As the wind energy is unlimited in certain areas around the world a cost effective digital charge controller can convert wind energy into electrical energy and can store it into batteries to be used when wind is not available or it can drive electrical load directly if batteries are charged and electrical power is available from wind turbine.

The control of battery charging is very much important as this is the only component that is to be maintained and due to its malfunctioning either because of overcharging or deep discharge complete wind system may not work properly.

Variable wind speed generates variable DC power, which can be higher or lower than required power to charge battery. The proper control of higher volts using DC-DC 'buck converter' keeps available power in safe limits and 4 stage battery charging mechanism always makes sure that battery is charged within safe limits.

Robust close loop buck control using PWM always monitors available power and power distributed among Load and Battery along with P&O maximum power point tracking ensures efficient utilization of available wind power. It can be concluded that if this cost effective and efficient charge controller is used for wind energy which can maximize the power generation and can solve the energy crises up to some extent.

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