IMPROVING BATTERY LIFE IN THE WIND TURBINE GENERATOR USING ULTRACAPACITOR

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ABSTRACT

Maintenance is performed to prevent failures, that is preventive maintenance or it is for correcting a failure event, which is corrective maintenance. The importance of Operation and Maintenance in wind turbine site is to ensure the Wind Turbine Generator (WTG) availability. When the WTG works, there would be possibility of issues such as errors / warning signals which may affects the availability of the WTG. In order to compete in the global market and to get repeated orders, turbine manufactures should ensure the WTG availability greater than 95% by reducing errors. My objective is to observe and collect the data related to repeated errors in the electrical system of WTG especially the battery of the pitch system, towards its working and to eliminate reoccurrence of such repeated errors by providing the complimentary solutions. In order to get optimum power generation in the WTG should get focusing towards wind direction by means of yawing and pitching operation. Lot of circuits, sensors and microprocessors are interlinked for smooth working of WTG. Any of the errors may lead to disconnection of WTG from electrical grid. Further, if any failure of WTG, during high wind season will lead to loss of power generation and customer dissatisfaction. An improvement of properties of battery can be achieved through supporting storage by an ultracapacitor energy storage.

Keywords: Wind Turbine Generator, Pitch System, Battery, Ultracapacitor

I. INTRODUCTION

1.1 Motivation

Generation of pollution free power has become the main aim of the researchers in the field of electrical power generation. The depletion of fossil fuels, such as coal and oil, also aid to the importance of switching to renewable and non-polluting energy sources such as solar, tidal and wind energy etc., among which wind energy is the most efficient and wide spread source of energy. Actions performed on a time- or machine-run-based schedule that detect, preclude, or mitigate degradation of a component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level. The importance of Operation and Maintenance in wind turbine site is to ensure the Wind Turbine Generator (WTG) availability. When the WTG works, there would be possibility of issues such as errors/warning signals which may affect the availability of the WTG. The understanding of wind turbine performance is important to be able to maximize the availability. An analysis of the failure statistics gives an estimate of the amount of downtime due to failures for each component in a turbine.

1.2. Project Objective

In order to get repeated orders and to compete in the global market it is required to increase the turbine availability to more than 95%. The prime objective of this project is to reduce the downtime of the wind turbine during high wind season and to increase the turbine availability.

The project mainly focuses on,

i. Observe and collect the data related to repeated errors in the electrical system of WTG
ii. Pin point the areas and errors related to the turbine availability
iii. To eliminate the errors, by providing suitable solution to increase the turbine availability.

II. PROBLEM PHASE

Operations and maintenance teams are committed to extracting longer life spans and higher returns from every wind turbine manufacture, which is offer a comprehensive range of value-added services and solutions. Operations and maintenance efforts ensure energy yield optimization in accordance with onsite climate and grid conditions. They also provide detailed monitoring services for every wind turbine erected. This combined synergy of business units and customer support network succeeds in providing customers with benefits that help satisfy their expectations of a global wind energy solutions provider.In order to compete in the global market and to get repeated orders, turbine manufactures should ensure the WTG availability greater than 95% by reducing errors.

2.1 Project Methodology

2.1.1 Electrical Systems

Wind energy is presently the fastest growing renewable energy source in the world. However, the industry still experiences premature turbine component failures, which lead to increased operation and maintenance (O&M) costs and subsequently, increased cost of energy (COE). To make wind power more competitive, it is necessary to reduce turbine downtime and increase reliability. Condition monitoring may help by reducing the chances of catastrophic failures, enabling cost-effective operation and maintenance practices, and providing inputs to improve turbine operation, control strategy, and component design. As compared with other applications, the wind industry started recognizing the benefits and importance of condition monitoring relatively late. Condition monitoring (CM), defined as the process of monitoring a parameter of condition in machinery such that a significant change is indicative for a developing failure, can potentially help by: 1) detecting incipient failures early, thereby reducing the chances of catastrophic failures; 2) accurately evaluating component health conditions, which has the potential to enable more cost-effective O&M; and 3) analysing root causes, which may provide the inputs for improved turbine operation, control strategy, and component design.

Controls are used for the following functions

- To enable automatic operation
- Keep the turbine aligned with the wind
- To engage and disengage the rotor speed
- To govern the rotor speed
- To protect the turbine from over speed or damage caused by very strong winds
- To sense malfunctions and warm operators of the need to perform maintenance of repair, etc

Controls for an individual machine may be integrated into a data- gathering system for a wind farm and a master computer can act as a supervisory control and diagnostic tool for the entire farm. For a large machine the cost of control represents but a small percentage of the total cost, and very elegant and precise controls can often be justified. Although passive controls do their own sensing and use natural forces for their actuations, active controls may use electrical, mechanical, hydraulic, pneumatic or other means in any combination to suite the desired purpose. Active control system depend upon transducers to sense many variables - rotation, speed, power produced, generator temperature, voltage, current, wind speed, pitch angle etc.- that will determine the control action needed. Transducers used for the control must be of high quality- rugged and extremely reliable. They must not only accurately measure the variable they are supposed to sense, but also refrain from responding to erroneous inputs. Another important point is that the machine should not be encumbered with so many interacting protective controls that it is hardly ever allowed to run.

Correlate between measured vibrations and operating values

- Splitting condition-based and operation-based values
- Comparison with specified thresholds
- Pre- and main-warning when thresholds are exceeded
- Tools for diagnosis (e.g. trend analysis)
- Measurement data storage

Condition Monitoring Benefits

- Reduce number of failures -> reduce number of repairs
- Reduce severity of failures -> reduce cost of repair
- Reduce turbine downtime -> reduce revenue losses

2.2 Wind Turbine Site Monitoring

SCADA system is the state-of-the-art solution developed in-house for all Wind Farms and Wind Turbines. It comprises of tools which are extensively used for operations, data acquisitions, analysis, and reporting.

- SCADA system features Control and Monitoring user interface. It provides direct access to Wind Turbines and Met Stations for detailed analysis and operations
- SCADA Reporting is a web-based solution, providing a reporting package for Wind Power Plants. SCADA Reporting Server is a central database where wind power plant data is hosted for reporting. It retrieves the 10-minute data from the Wind Turbine and Met Station from all connected wind power plants

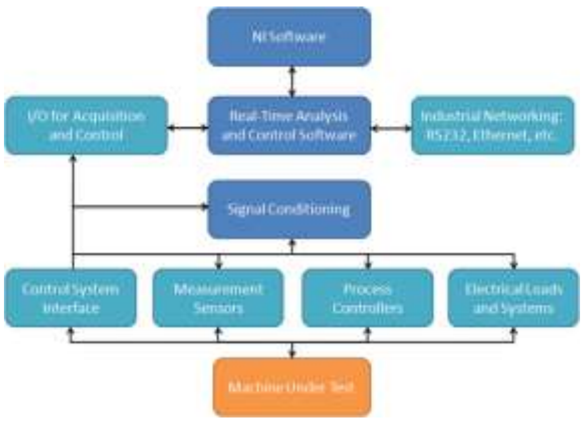

Fig.1 Wind Energy Monitoring System

2.3 Errors Happening in the Site

1. Level 4 Errors

2. Level 3 Errors

2.4 Analyzing Errors

Recent economic and technical developments such as the pressure to reduce the overall cost of electricity generated by wind turbines, the necessity to reduce O&M costs as well as increased emphasis on reliability and predictability of power production make it urgent to find a technical solution to that question. Load reduction is a key element of the solution. In addition, load reduction gains an increasing importance due to the trend towards larger wind turbines. Individual pitch control (IPC) plays a key role in compensating loads. So what is IPC? Any pitch control system allows control of the turbine speed and consequently the power output. It also acts as a brake, stopping the rotor by turning the blades. Moreover, pitch control, especially an IPC system, has a role in reducing fatigue loads on the turbine structures. Recently developed wind turbines are variable speed turbines capable of adapting to various wind conditions. This adaption is realized via new generator concepts on the one hand, and a pitch control system on the other hand. Pitch control means the turning of rotor blades between 0° and 90°. When wind speeds are below rated power, typically below 12 m/s, the rotor blades are turned fully towards the wind which means that the pitch is positioned at 0°as shown in the figure 1.

At increasing wind speeds the pitch of the blades is controlled in order to limit the power output of the turbine to its nominal value. When wind speeds reach a predefined threshold, typically 28 m/s, the turbine stops power production by turning the blades to a 90° position.

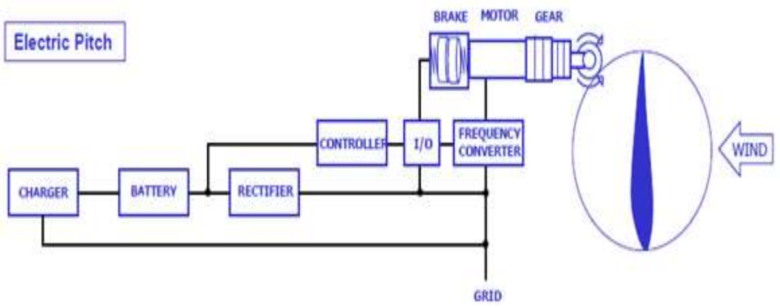

Fig.2 Electric Pitching

Collective pitch control adjusts the pitch of all rotor blades to the same angle at the same time. In contrast, IPC dynamically and individually adjusts the pitch of each rotor blade. Based on current individual loads this pitch adjustment is carried out in real-time. The main benefit of IPC is the reduction of fatigue loads on the rotor blades, the hub, and mainframe and tower structures. In order to compensate these loads, especially symmetric loads caused by inhomogeneous wind fields, the pitch of each rotor blade has to be adjusted independently from the other blades. A reduction of fatigue loads has two considerable advantages: It allows lighter designs and translates into longer lifetimes of wind turbines. What is meant by lighter designs? In cases where components are designed according to fatigue loads, a reduction of these loads allows savings in cost and material notably for the rotor blades and the tower structure, which are the most expensive elements of a wind turbine. Moreover, lighter rotor blades enable a more efficient turbine, especially in low wind conditions. Finally the load reduction through IPC gives designers the option to develop low wind turbines from existing designs, which means a reduction of time to market.

Errors related to pitch system due to battery voltage

1) During the startup of turbine, testing the Battery voltage of all battery banks through safety speed test is one of the tests conducted through program. If the turbine is failed to complete the test in limited time period we will get this alarm
2) Missing of the 24V DC from the battery surveillance sense communication of blade
3) VOLTAGE WARNING Problem with the battery voltage value is lesser than the specified parameter (230V) of blade
4) VOLTAGE STOP Problem with the battery voltage value is lesser than the specified parameter (220V) of blade
5) Alarm is called if the digital input of the frequency converter 1 is low
(Missing of the 24V DC from the battery surveillance sense communication of blade)
6) Alarm is called if the digital input of the frequency converter is low
(Missing of the 24V DC from the DC to DC converter (290V DC / 24V DC) of blade)
Important components in the hub panel are

1) Frequency converter (3 no)
2) DC-DC power converter (3 no)
3) Battery surveillance (3 no)

1. Frequency converter is also called Frequency Drive or only "Drive". The Frequency converters are used to control the speed of Pitch Motor. Pitch Motor pitches the blade. Frequency converter converts AC to DC and then DC to variable AC which is fed to 3 phase AC pitch motors. The speed control is achieved by Varying voltage and Frequency The input 3 phase 230 VAC converted to DC. DC is inverted to variable AC through Variable voltage variable frequency (VVVF) Frequency converter by using IGBT-Insulation Gate Bipolar Transistor. Output of Frequency converter is fed to 3 phase Induction Motor (Pitch Motors).
2. Purpose of Battery Bank in WTG is pitching the blades to the 90 Degrees after Grid failure. Power Supplies (DC to DC converters) are located in the Hub panel which provides control voltage +24 V DC to 3 Frequency Converter in case of Grid fails. It converts Battery bank voltage 264 VDC to 24 V DC. Input Voltage 90...350 V AC/DC (through Battery Bank voltage 264 V in Hub).
3. 3 no.s Battery Surveillance units are used to monitor Battery voltage of 3 Battery Banks. Battery surveillance unit is Electronic limit relay used to monitor healthiness of Battery in the Hub by measuring Battery voltages during battery test (Grid failure time). Battery charger located in Top (Nacelle)control panel which is used to charge the Battery banks in the Hub. The charger use constant current method to keep the battery in fully charged state. Output (300 VDC) of Battery charger is connected to Hub through Slip rings. Battery charger input 195-264V AC. Output 300V DC,2.1A

III. SOLUTION PHASE

3.1 Electric Pitch System – Challenges

Batteries - difficult to monitor, low power at low temperature and a frequent need for replacement. If a failure (loss of production or extra service cost) happens, the turbine must be brought to a controlled position – again and again

Table I. – Features of Ultra-Capacitors and Batteries

Ultra capacitor	Battery
Low energy density	High energy density
Very high power	Medium power
Very long cycle life	Short cycle life
Voltage depends on the state of charge	Voltage relatively constant
Sized to fit power profile	Sized to fit energy profile
High efficiency	Medium efficiency
Performance decreases smoothly	Performance decreases sharply
Quick charges/discharges	Slow charges/medium discharges
Good performance at very low temperatures	Bad performance at very low temperatures

A high-performance on-board electric energy storage is the main obstacle to development of wind turbine components. There are imposed many requirements on electrical energy sources, as high power and energy density, long cycle-life, reliability, wide temperature range and no emission of pollutants. Installing only one type of energy storage/source ie Battery, is often insufficient. So hybridization of the source enables to solve some key problems encountered. Lithium battery provides the energy density at the level of 80-110Wh/kg and power density at the level of 500W/kg.

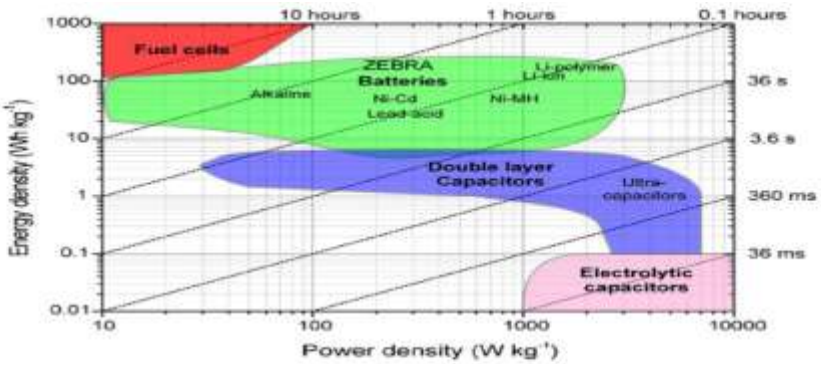

Fig.3 Energy and Power Density, Batteries and Ultra Capacitors

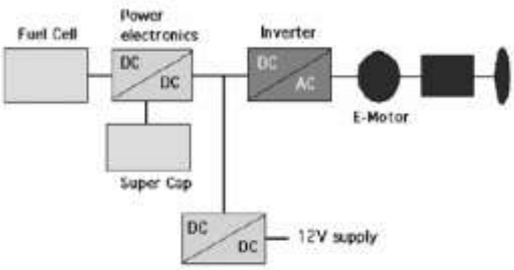

Fig.4 Hybrid Energy Storage Systems :(Passive Hybrid)

3.2 Ultra Capacitors Model

The simplified ultra-capacitor model is shown in above figure this model is composed of a resistor R, which is responsible for the electrical losses due to non-zero internal resistance of an ultra-capacitor, and a capacitor C, which corresponds to ultra-capacitor's capacitance. Model does not take into account the transient voltage change indynamic state, but is sufficient to evaluate power losses. Value of R resistance is set to ESR (Equivalent Series Resistance) for worst case scenario, i.e. highest DC current. The change in capacitance and resistance related to the temperature is calculated in initialization commands.

In order to optimize merging of ultracapacitors and batteries into one pack power electronicconverter is required to manage power flow between the main DC bus of drive converters. Figure 1b shows oneinstance of active hybrid. This topology allows direct exchange of energy between the load and capacitorswithout the use of converter, which is advantageous for frequent vehicle dynamic states. The main flow of energyfrom the batteryis controlled by a DC-DC converter, which enables power division but increases losses. Moreover,such a system imposes constraints on the ultracapacitor voltage acceptable values. The goal of control strategy of active hybrid energy storage is to cover average power demand from main source (battery) and at the same time to cover all power fluctuation related to pitching operation from ultracapacitors. The ultracapacitor source is recharged during grid availability or from batteries at periods of low power demand.

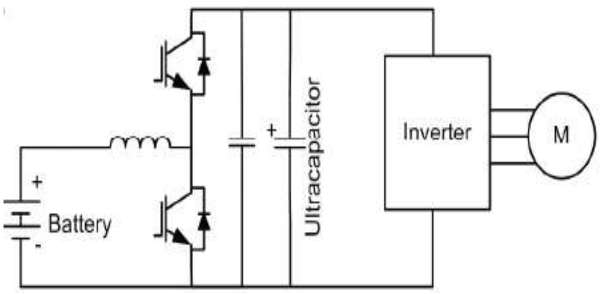

Fig.5 Active Hybrid with Low Voltage Batteries and High Voltage Ultra Capacitors

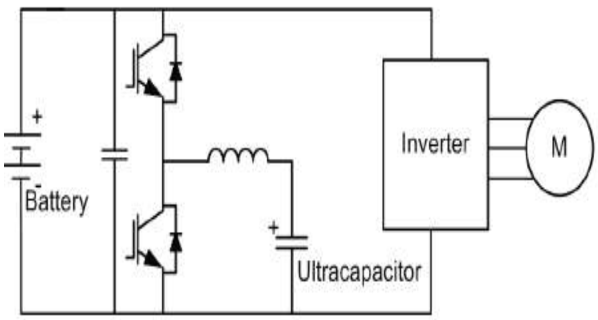

Fig. 6 Active Hybrid with Low Voltage Ultra Capacitors and High Voltage Batteries

IV. RESULTS AND DISCUSSIONS

4.1 Battery Improvement

An increasing number of portable electronic devices such as laptops and mobile phones incorporate batteries as power supplies. Many such devices draw high power, pulsed currents (Fig. 8), and current profiles consisting of short, high current bursts result in a reduction of battery performance. Using supercapacitors in combination with a battery is therefore an optimal solution. A supercapacitor can relieve the battery of the most severe load demands by meeting the peak power requirements, and allowing the battery to supply the average load. The reduction in pulsed current drawn from the battery results in an extended battery lifetime . Many electronic devices also include premature shutdown circuitry. These devices will power-down upon the detection of a low voltage, preventing loss of data. A noisy supply voltage can sometimes trigger these shutdown circuits. The supercapacitor will help prevent premature shutdowns by reducing the severity of voltage transients.

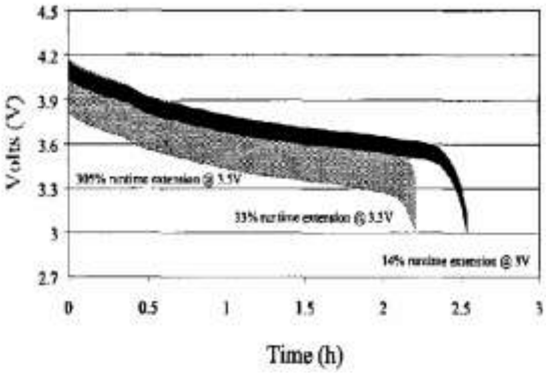

Fig.7 Runtime Extension When Using an EDLC in Combination With a Battery.

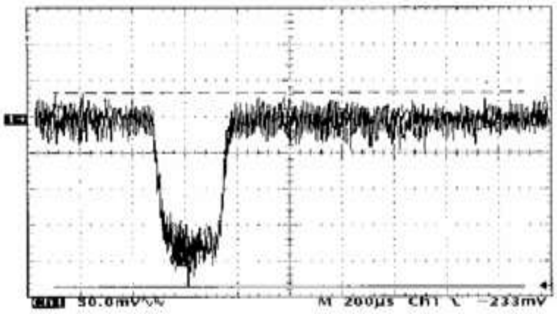

Fig.8A Battery Subjected to a Pulsed Current Without a Ultracapacitor

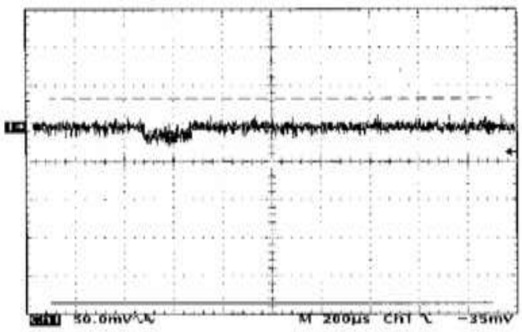

Fig. 9 A Battery Subjected to a Pulsed Current with Ultra-Capacitor

Figure 9 shows the effectiveness of a super capacitor in reducing voltage transients. The top part of the diagram shows a 10.8 V lithium-ion battery pack subjected to a 2 A current pulse, while the bottom part of the diagram shows the same battery coupled with a 7 F, 5 m/s super capacitor subjected to the same current conditions.

V. CONCLUSION AND FUTURE SCOPE

I hope that this failure analysis will be more useful to the wind industries / manufacturers for reducing the downtime and increase the turbine availability greater than 95% and customer satisfaction. The transient part of the load is supplied by ultracapacitor only which relieves the battery of supplying peak power and it leads to reduced battery size and increased battery life. An efficient control strategy for managing the energy and power flow in a pitching operation for the required frequent operation and thus achieves the best possible utilization of all the energy source without compromising the performance of the wind turbine generator. Ultra capacitors aren't extended as a standard in many applications (usually because of their price), their use should be justified because of the energy savings achieve and also due to the longer cycle and the mistreatment resistance that characterize the ultra-capacitors in comparison with batteries. The importance of Operation and Maintenance in wind turbine site is to ensure the Wind Turbine Generator (WTG) availability .An analysis of the failure statistics gives an estimate of the amount of downtime due to failures for each component in a turbine and the replacement of the converter and inverter parts for the pitch drive system with suitable new technologies

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