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An Initiative Towards Efficient and Sustainable V2G Technology Fed STATCOM for Grid connected Wind Energy System

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Abstract: - The proliferation of renewable energy sources, particularly wind energy, has significantly contributed to the diversification of the global energy mix and the mitigation of greenhouse gas emissions. However, the intermittent nature of wind power generation poses challenges to the stability and reliability of the power grid. This paper explores the integration of Vehicle-to-Grid (V2G) technology with Static Synchronous Compensator (STATCOM) for grid-connected wind energy systems. Novelty. Vehicle-to-Grid (V2G) technology enables bidirectional energy flow between electric vehicles (EVs) and the power grid, allowing EV batteries to serve as energy storage devices. This capability can be leveraged to support grid stability and reliability by utilizing EV batteries to store surplus wind energy during periods of high generation and release it back to the grid during periods of low generation or high demand. Purpose. This effectively mitigates the intermittency and variability of wind power, smoothing out fluctuations and improving grid stability. Methods. By employing V2G technology and leveraging the dual-purpose battery solution can compensate the grid voltage fluctuations and improve power factors in grid-connected wind energy systems, enhancing overall system stability and reliability. Results. The Hystersis current controller (HCC) scheme is used for controlling STATCOM to enhance the dynamic performance. Practical value. The system is simulated in its entirety using the matrix laboratory (MATLAB) . The proposed sustainable model will pave the way for maintaining the true power supply under varying wind conditions.

Keywords: Vehicle to grid techniques, STATCOM , Hysteresis current controller, Power quality indices

I. INTRODUCTION

The quality of the power is becoming a bigger concern for both electric providers and end customers. Any deviation in the nominal value of voltages, frequency limits and fault current that causes the customer's equipment to malfunction or fail can be referred to as having poor power quality. Adding wind energy to the grid system causes power quality issues. The equipment used to reduce power quality problems is known as a customer power device (CPD). There are three main types of compensating devices in the family: STATCOM (static synchronous compensator), UPQC (unified power quality conditioner), and DVR (dynamic voltage restorer). Power quality concerns are evaluated by comparing the output of a battery storage system (BSS) coupled with a static synchronous compensator (STATCOM) at the common coupling point (PCC) between a wind energy system and the electric grid. During regular operation, a wind energy system's output power fluctuates constantly [1],[2],[3],[4]. The main causes of these power variations include wind shear, the effect of tower shadow, turbulence, and the control block of the plant. To regulate the power difficulties, attention must be paid to the designed network. Harmonics, voltage sag, and swell are the primary issues with power quality [8]. One of the simplest methods of operating a wind production system is to connect an induction generator directly to the grid [17]. Two of the induction generator's inherent advantages are its affordability and durability. However, the magnetization of an induction generator requires reactive power. The useful power generated due to wind-related variations can have a considerable impact on the device's reactive power absorption and terminal voltage [5],[6],[7]. When wind installations are integrated into the grid, power quality concerns need to be addressed [9]. A control solution utilizing the STATCOM technique has been suggested. The stability of the grid can be supported by V2G-enabled vehicles by adding more power during times of peak demand or absorbing excess power during times of low demand8. The V2G fed STATCOM as shown in Fig. 1. is used for regulating voltage levels and enhancing power quality by offering reactive power[10],[11],[12]. With V2G technology, the grid may be made more flexible by better managing intermittent renewable energy sources like wind power by leveraging the energy storage capacity of electric vehicles.

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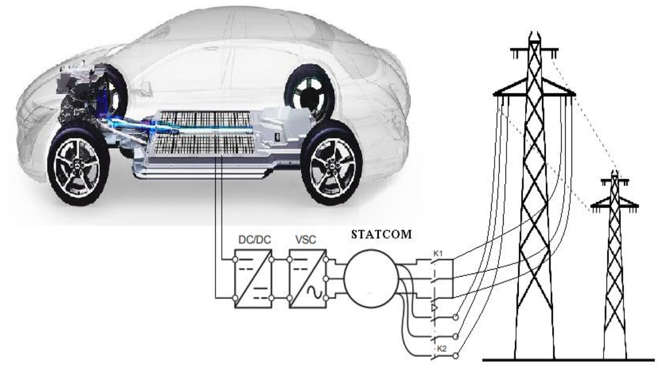

Fig. 1 Vehicle to Grid connected system

Improved power quality, increased grid resilience, and increased overall efficiency of renewable energy integration can be achieved by integrating V2G technology with a STATCOM in a grid-integrated wind system. The DC link of a three-phase inverter, which is coupled at the common coupling point, has capacitance. At the PCC, STATCOM introduces variable-frequency, variable-amplitude compensatory current[13],[14],[15]. The grid is connected to the source utilities, wind system and STATCOM with a battery system[18]. To ensure that the supply current is free from harmonics and attains unity power factor, the current-governed STATCOM-based voltage source inverter distributes current into the grid[19]. The enhanced power quality results from the injected current canceling out the harmonic and reactive components present in an asynchronous generator and the load. The proper shutting and unlocking of the inverter valves on STATCOM results in the injection of current.

II. PROPOSED TOPOLOGY

Pitch control is used in fixed-speed topologies for wind generation in this configuration. The suggested method makes use of the induction generator because of its built-in short-circuit safety, simplicity, and ability to handle both constant and variable loads without the need for a separate field circuit. The available wind power output is displayed as follows:

$$P_{available} = 0.5\ d\ A\ S_w \quad (1)$$

Where d = air density (kilogram /cubic meter), A = Turbine blade area (m^2), S_w= wind velocity (meter /sec).

The extraction of all kinetic energy of wind was impossible.

CT_p = coefficient of turbine power, and is given by:

$$P_{ml} / P_{available} = CT_p \quad (2)$$

The mechanical power (P_{ml}) is given by

$$P_{ml}=(1/2)\rho\ B_r^2\ S_w^3\ CT_p \quad (3)$$

where B_r = Blade radius {m}.

The phase voltage (V_{pa}, V_{pb}, and V_{pc}) in a three-phase balanced system is used to compute the amplitude of the effective value of voltage, which is expressed as mean voltage. V_m:

$$V_m = \{2/3(V_{pa}^{\ 2} + V_{pb}^{\ 2} + V_{pc}^{\ 2})\} \quad (4)$$

The ratio of AC phase voltage to the mean voltage was found to obtain the unit phase voltages as shown below:

$$U_{ia} = V_{pa} / V_m \quad (5)$$
$$U_{ib} = V_{pb} / V_m \quad (6)$$
$$U_{ic} = V_{pc} / V_m \quad (7)$$

The unit vectors of voltages are used to calculate unit reference currents.

A. Power Quality Enhancement System.

To achieve regulating voltage, Battery Storage System (BSS) serves as an energy storage component. The BSS is ideally suited for STATCOM to stabilize the grid due to the potential for quick injection or absorption of reactive power and will naturally keep dc capacitor voltage constant. Additionally, it quickly regulates the distribution and communication network. When a system experiences power fluctuations, the

BSS can be utilised to offset power fluctuations in a system through charging and discharging processes. Battery and the STATCOM's dc capacitor are linked in parallel. At common coupling point , Induction generator and non-linear load interface, are connected to the V2G powered static compensator and energy storage device in the grid system are as shown in Fig. 2. To keep the grid system's power quality standards, the static compensator output is adjusted in accordance with the control strategy.

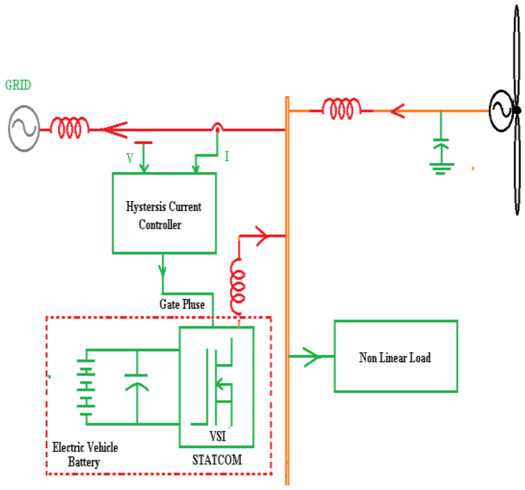

Fig. 2 Proposed V2G STATCOM based Grid connected wind system

The Bang-bang control schemes are employed as control strategy for STATCOM, which specify the static compensator operation in the grid. The asynchronous generator and nonlinear load in the grid system are supported by reactive power through the suggested V2G fed STATCOM. The STATCOM continuously checks grid stability factors including voltage and frequency. Depending on the wind speed and other environmental conditions, the wind turbines produce electricity. The grid connection allows the generated electricity to be fed into the grid.

The STATCOM continuously modifies its output in order to supply the grid with reactive power. In particular, it helps control voltage levels and maintain grid stability during changes in wind power output or other disruptions. When parked and plugged in for charging, electric vehicles using V2G technology are connected to the grid. EVs with V2G capability can take use of a number of grid functions, including load balancing, peak shaving, and frequency management. In order to efficiently meet grid requirements, these vehicles are operated in coordination with the STATCOM.

B. Feedback controller loop

The hysteresis controller operates based on the principle of comparing the actual value of a controlled variable (e.g., grid voltage) with predefined upper and lower thresholds. When the actual value exceeds the upper threshold, the controller activates a corrective action (e.g., injecting reactive power) is shown in Fig. 3

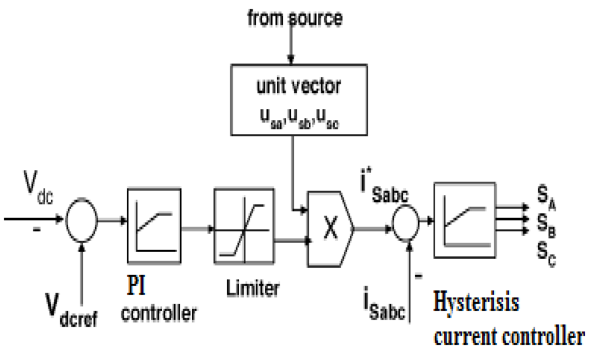

Fig. 3 Hysteris Controller Scheme

Similarly, when the actual value falls below the lower threshold, the controller deactivates the corrective action. This hysteresis behaviour prevents continuous switching of the control action, providing robust and fast response to variations in the controlled variable.

III. RESULTS AND DISCUSSION

The proposed system is compared with the uncompensated system using MATLAB simulation Software. The test has been carried out for varying wind speed condition at the time interval t=0.8 secs to t=1.2 secs such as the wind speed falls at the time t=0.8 secs and increases slowly at time t=1.2secs. The rotor speed and electromagnetic torque of the Wind turbine for varying conditions are observed and shown in Fig. 4. and Fig. 5 respectively . The wind speed falls from 100 rad/secs to 20 rad/ secs at the time t= 0.8 secs and regains to 100 rad/ secs at the time t=1.2 secs.

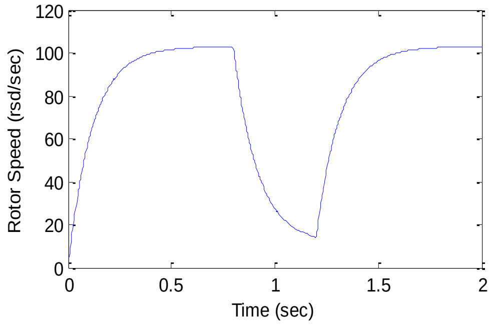

Fig. 4 Rotor Speed of Wind Turbine

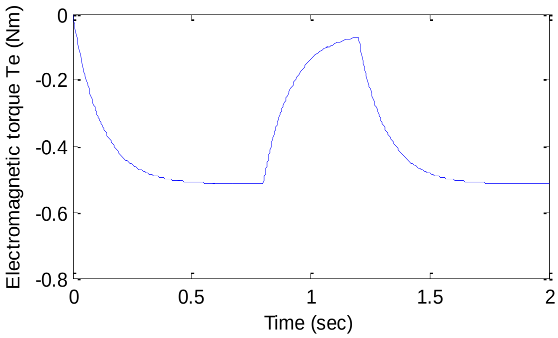

Fig. 5 Electromagnetic torque of Wind Turbine

The Performance of the induction generator based wind turbine connected to the grid without compensation techniques are represented as below. The Voltage fluctuated in the grid connected wind system, this will introduces disturbance in the grid side for the uncompensated system. The stator current of three phases (ia, ib, ic) are reduced at the time interval t=0.8 secs to t=1.2 secs are depicted in the Fig. 6.

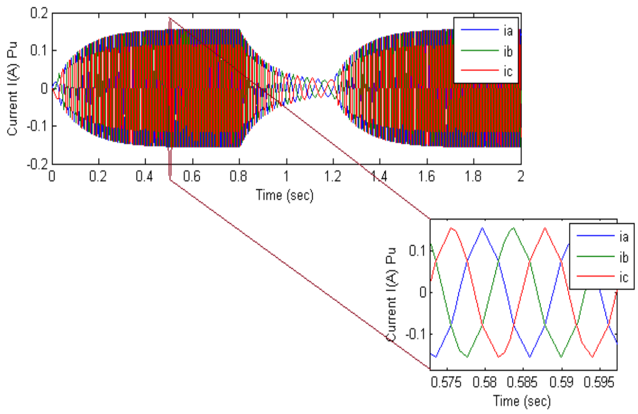

Fig. 6 Stator Current without compensator

The Fig. 7 depicts the reduced voltage waveforms of three phase system without compensation for varying wind speed.

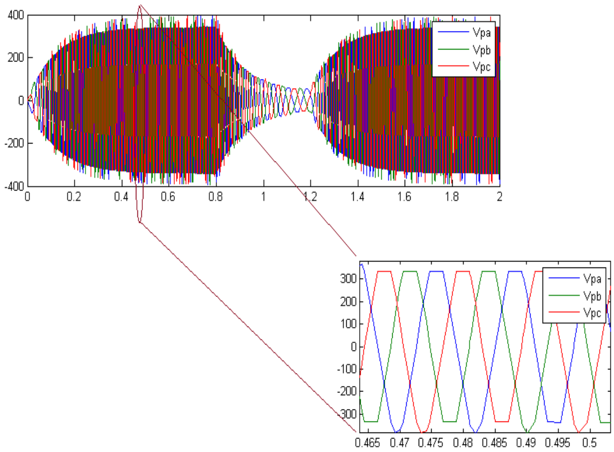

Fig. 7 Three phase voltages without compensator

Due to the effect of disturbances injected in the grid side, the power factor of system was reduced from 0.8 to 0.65 for varying wind speed as shown in Fig.8 .

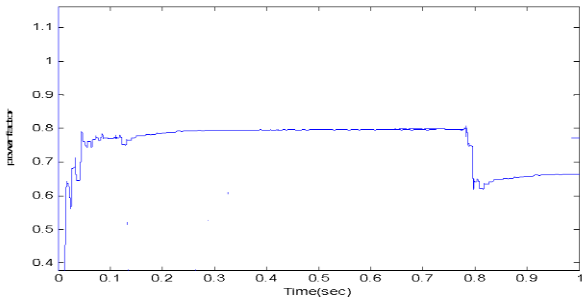

Fig.8 Power factor without compensation.

The Performance of the induction generator based wind turbine connected to the grid via V2G fed STATCOM are shown below. In this proposed system , V2G fed STATCOM plays a crucial role to enhance the voltage stability and reduces the power quality issues.

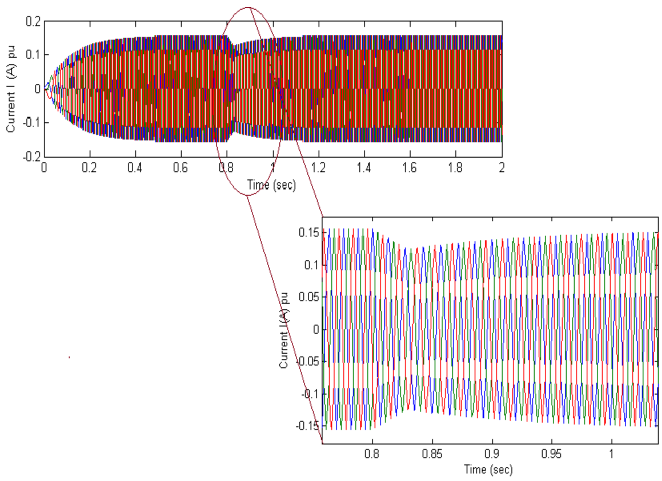

Fig. 9 Stator Current with compensator

After compensation, the current and voltage waveform of the three phase systems for varying wind speed conditions at the time interval t=0.8 secs to t=1.2secs are maintained steady state are shown in Fig.9 and Fig. 10. respectively

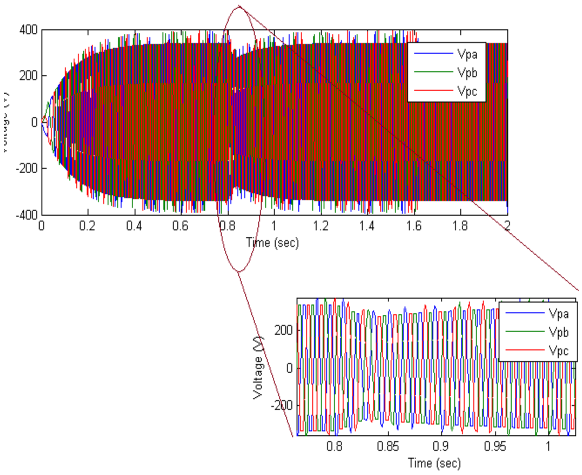

Fig.10 Three phase voltages with compensator.

For the compensated system, the power factor of the grid connected wind system was increased and attains a value of 0.8 for varying wind speed as compared with uncompensated systems are shown in Fig. 11.

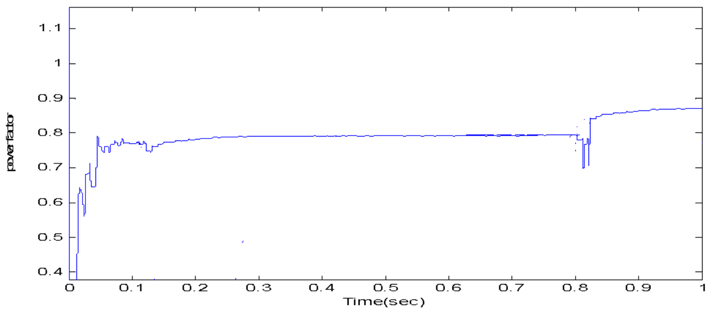

Fig. 11 Power factor with compensation.

IV. CONCLUSIONS

The proposed method enhances the power quality of grid-integrated wind systems by utilizing the STATCOM-based compensating strategy for nonlinear loads. The MATLAB software was used to develop the operation of this control scheme. V2G fed STATCOM effectively compensates the system voltages and increase the power factor of the three phase grid connected wind system for varying wind speeds. This template provides authors with most of the formatting specifications needed for preparing electronic versions of their papers. All standard paper components have been specified for three reasons: (1) ease of use when formatting individual papers, (2) automatic compliance to electronic requirements that facilitate the concurrent or later production of electronic products, and (3) conformity of style throughout a conference proceedings. Margins, column widths, line spacing, and type styles are built-in; examples of the type styles are provided throughout this document and are identified in italic type, within parentheses, following the example. PLEASE DO NOT RE-ADJUST THESE MARGINS. Some components, such as multi-leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

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