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Synchronization and Reactive Current Support of PMSG Based Wind Farm during Severe Grid Fault

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ABSTRACT

Grid codes require wind farm to remain on-grid and inject specific reactive current when grid fault occurs. To satisfy the requirements, reactive power devices such as the static synchronous compensator (STATCOM) are usually used in modern wind farms. In order to produce reactive currents, the wind energy generation system (WECS) and the STATCOM are normally controlled with the phase locked loop (PLL)-oriented vector control methods. The paper is about synchronization and reactive current support of PMSG.

***KEYWORDS:** PMSG, STATCOM, WECS, PLL*

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I. INTRODUCTION

With more and more wind power integrated into the grid, its impact on the reliability and stability of the power system becomes the main concern all around the world. To deal with such situation, grid codes have been proposed by the grid operators to standardize the characteristics of the wind energy conversion system (WECS). One of the codes, namely low voltage ride through (LVRT) code, requires the WECS to stay connected and inject expected reactive current to support the grid when grid fault occurs. It has been reported that the permanent magnet synchronous generator (PMSG) based WECS has the advantages on the LVRT in contrast to other types of wind turbines because of its capability and flexibility on the active and reactive power controls with the full-scale converter. The LVRT schemes for the PMSG based WECS have been widely discussed in the previous studies. The main difficulty of the WECS control during fault period is to maintain the DC-link voltage of the power converter. Different schemes have been proposed and verified in previous literature, such as the coordinating active power control of the generator- and grid-side converters; DC chopper based active power dissipation scheme, etc. It is proven that the PMSG based WECS can meet the LVRT code requirements easily due to the control flexibility of its full-scale converter. Even so, nowadays, STATCOM becomes the standard equipment in current wind farms to stabilize the grid voltage, which is usually required by the grid operators. In fact, the STATCOM is necessary for the wind farm especially in the unsymmetrical grid fault situation. As indicated in, the positive-sequence reactive current capability of the PMSG based WECS would degrade up to 35% when the phase-to-phase fault occurs. Synchronizing with the power grid is the fundamental of reactive current supply for both WECS and STATCOM. Although with enough reactive current capacity, the wind farm can still fail to ride through some severe grid faults due to loss of synchronization (LOS). Generally, LOS phenomenon can occur not only in the wind farm but also in any other types of grid-tie voltage source based converters (VSCs). It is reported that many factors, including short-circuit ratio (SCR), voltage sag percentage, phase-locked-loop (PLL) parameters and VSC active power capacity, can affect the grid synchronization of the VSC. Based on the small-signal analysis, the interaction between the PLL and the power control dynamics of the VSC is reported to be the dominant reason of LOS issue. However, such conclusion hardly holds true in the transient fault period during which the VSC's operation points change. Large signal analysis could be the proper tool in LOS study but its physical mechanism should be further explained. Some previous studies proposed effective solutions to avoid LOS. A modified active current injection scheme is proposed based on the steady-state circuit analysis. The dynamic performance during the fault transient is not discussed. It is reported that LOS can be avoided by reducing the active current of the VSC but it can hardly be employed in the LVRT period when only reactive currents are required by the grid codes. Other schemes tried to reconstruct the PLL to solve the LOS problem, such as the isolated PLL, the switched PLL or even eliminating the PLL with virtual synchronous generator (VSG) technology. In fact, those schemes keep the synchronous rotational angle stable by slowing down the dynamic response of the PLL. During fault transient, the oriented phase angle cannot track the grid voltage vector angle accurately. Therefore, the active and reactive currents would be out of control, which is not preferred by the grid codes. Moreover, most of the previous studies on LOS issue are based on the assumption that the VSC has an ideal DC voltage supply. Such assumption cannot hold true in the PMSG based WECS because the DC voltage is usually controlled by the grid side converter, which may fluctuate with the input power. Even though the DC voltage could remain almost constant with a high-gain controller, the DC voltage control loop would interact with the synchronization loop then resulting in LOS problem. The entire above problem occurs in the STATCOM and is even more serious since it has no capability on active current regulation.

II. RESEARCH OBJECTIVES

- To study different Active Power Devices used in modern wind farms
- To propose a coordinating control scheme for the wind farm to keep synchronization during severe fault period.
- The STATCOM would compensate the reactive current capacity loss of the WECS due to its active power compensation.
- To stable the DC-link voltage.
- To design the Matlab based system of the PMSG based wind farm with conventional control strategy during severe fault.
- To Design the Matlab based system of the PMSG based wind farm with proposed strategy.

III. RESEARCH METHODOLOGY

This research work will adopt a research methodology that combines the theory model with empirical evaluation and refinement of the proposed scheme on MATLAB simulation tool. MATLAB is a useful high-level development environment for systems which require mathematical modelling, numerical computations, data analysis, and optimization methods. This is because MATLAB consists of various toolboxes, specific components, and graphical design environment that help to model different applications and build custom models easier. Moreover, the visualization and debugging features of MATLAB are simple.

IV. RESULTS AND DISCUSSION

The following figures show system response of the PMSG-based wind farm with conventional control strategy during severe fault.

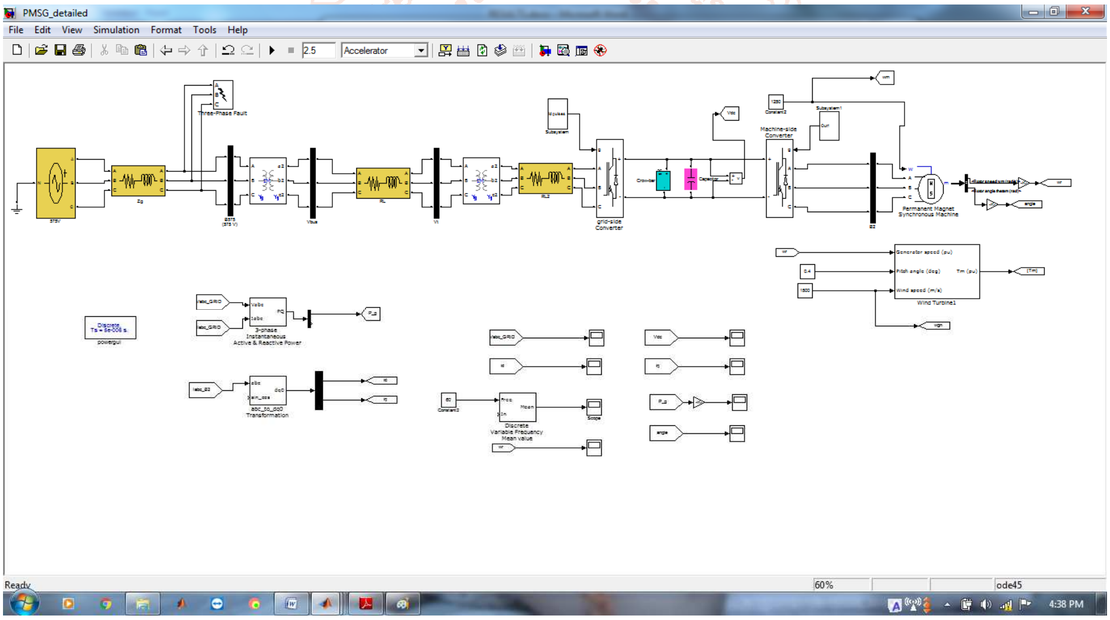

Figure 1.1: The PMSG overview

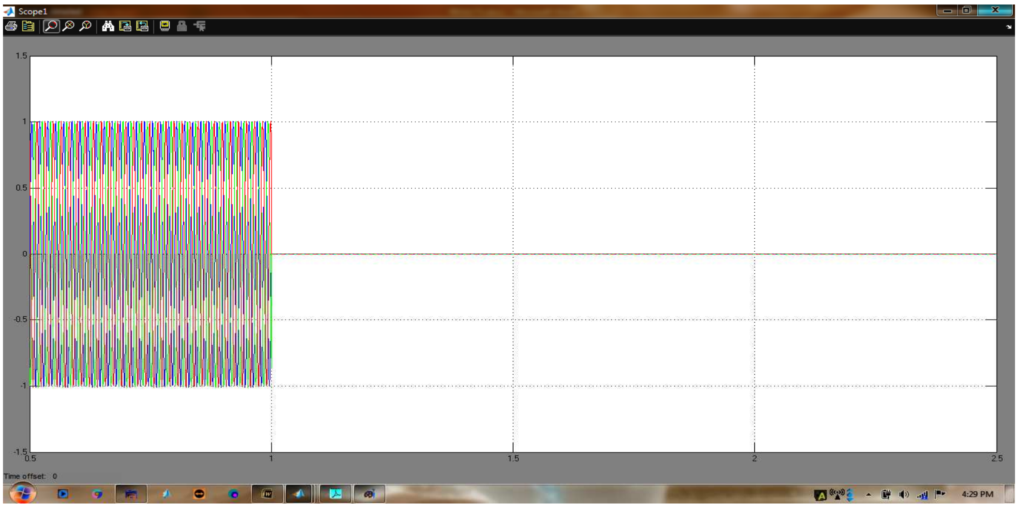

Figure 1.2: VGCP in Conventional System.

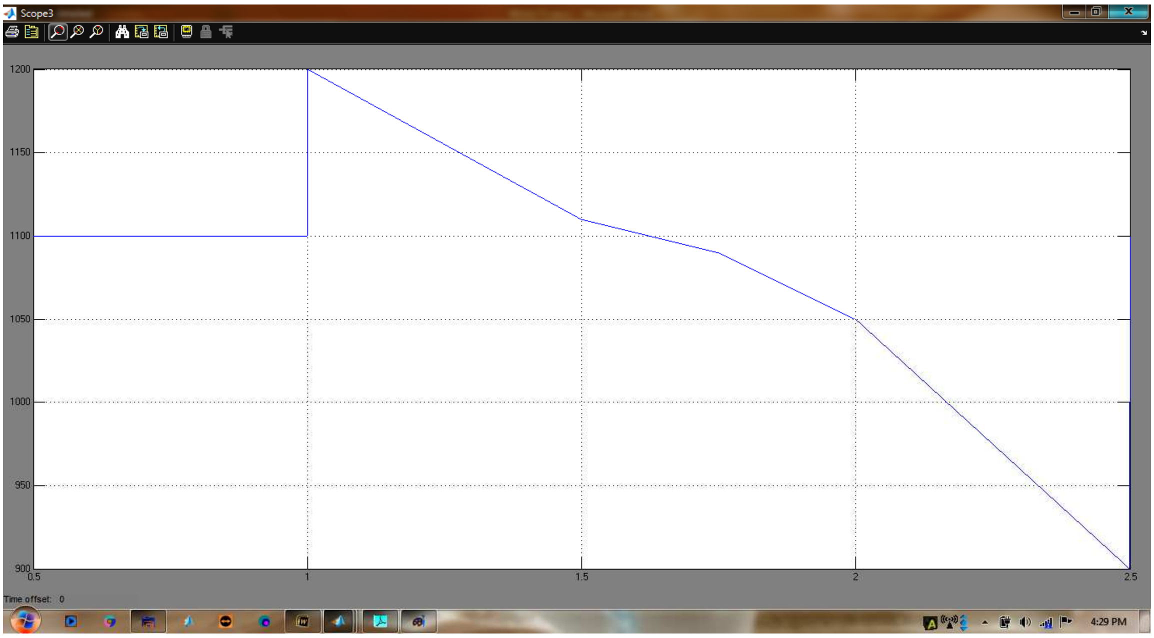

Figure 1.3: VDC in Conventional System.

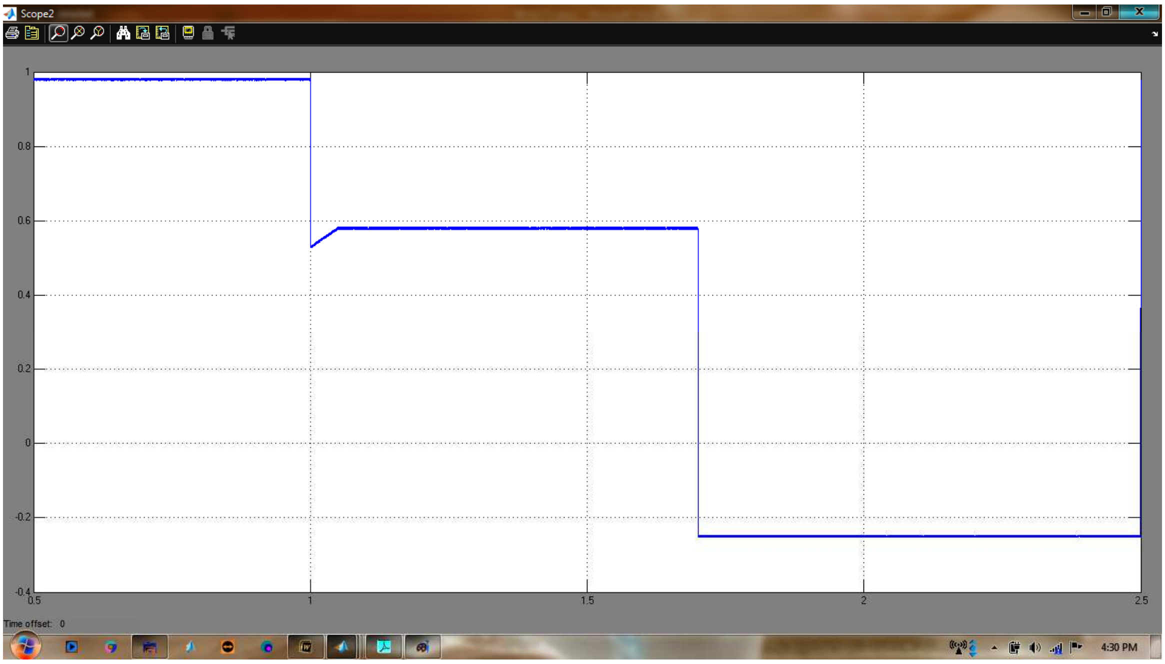

Figure 1.4: Id in Conventional System.

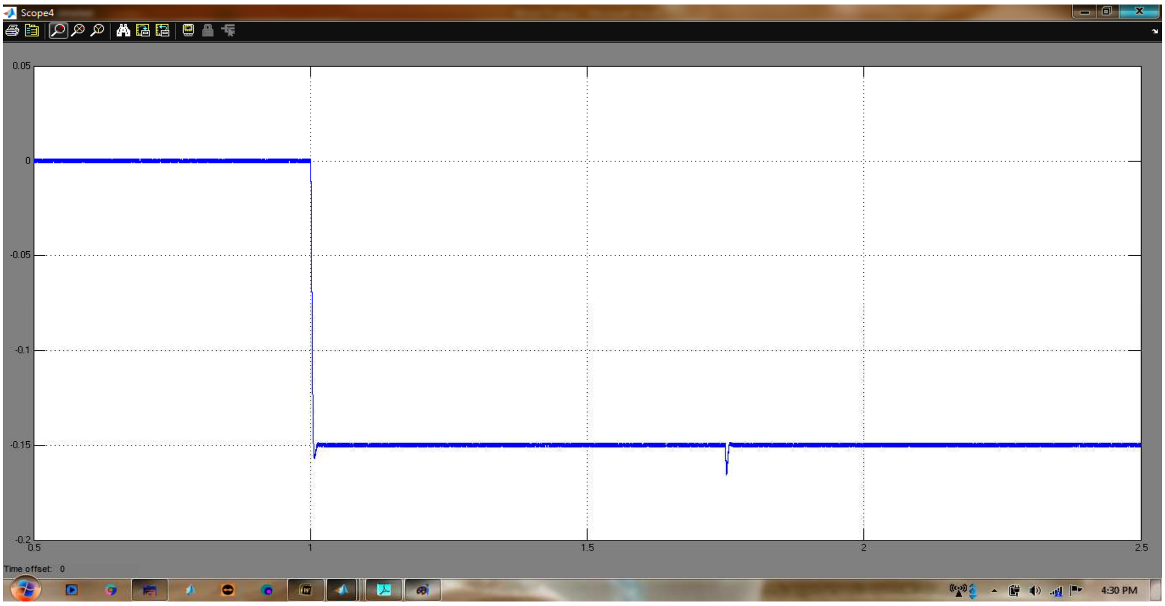

Figure 1.5: Iq in Conventional System.

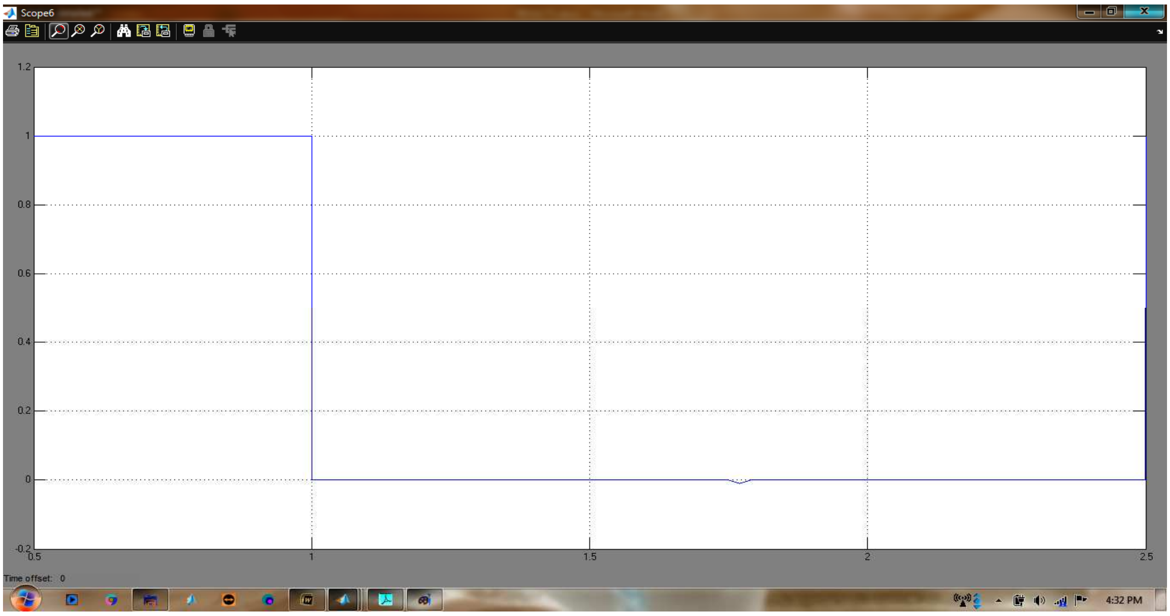

Figure 1.6: Pg in Conventional System.

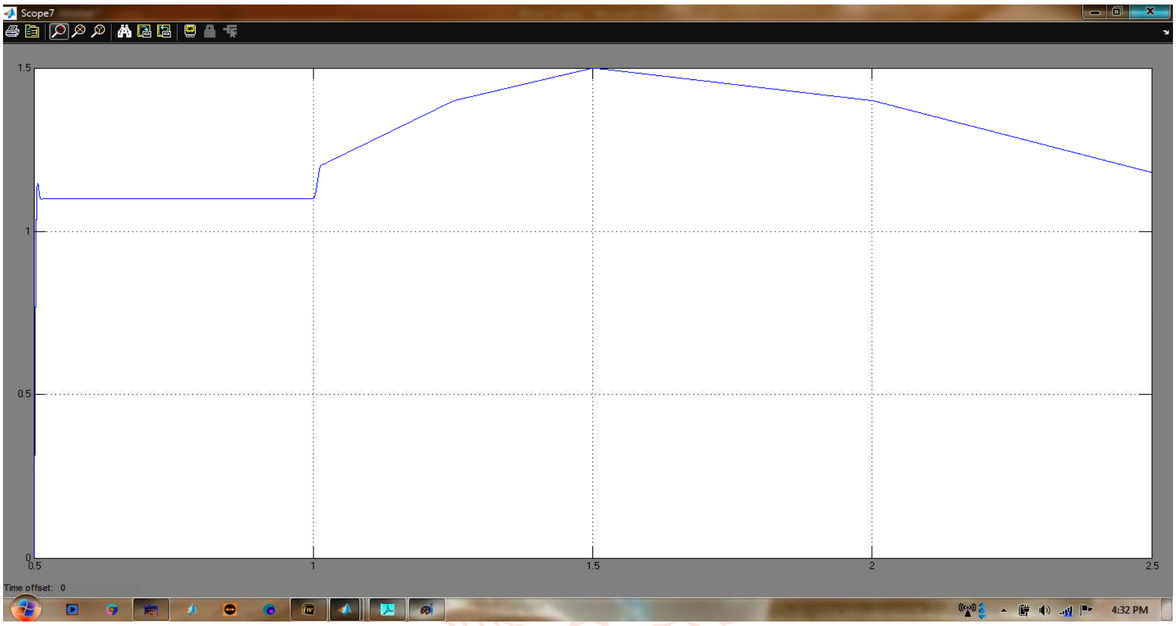

Figure 1.7: Wr in Conventional System.

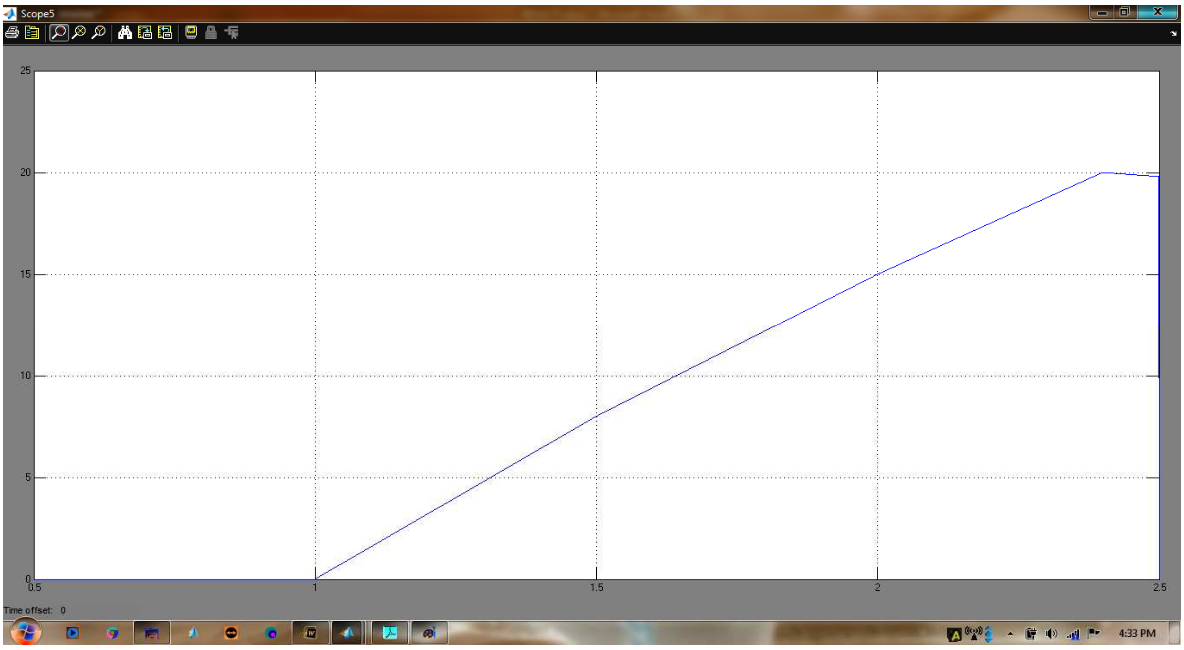

Figure 1.8: Angle in Conventional System.

The following figures show system response of the PMSG-based wind farm with proposed strategy during severe fault.

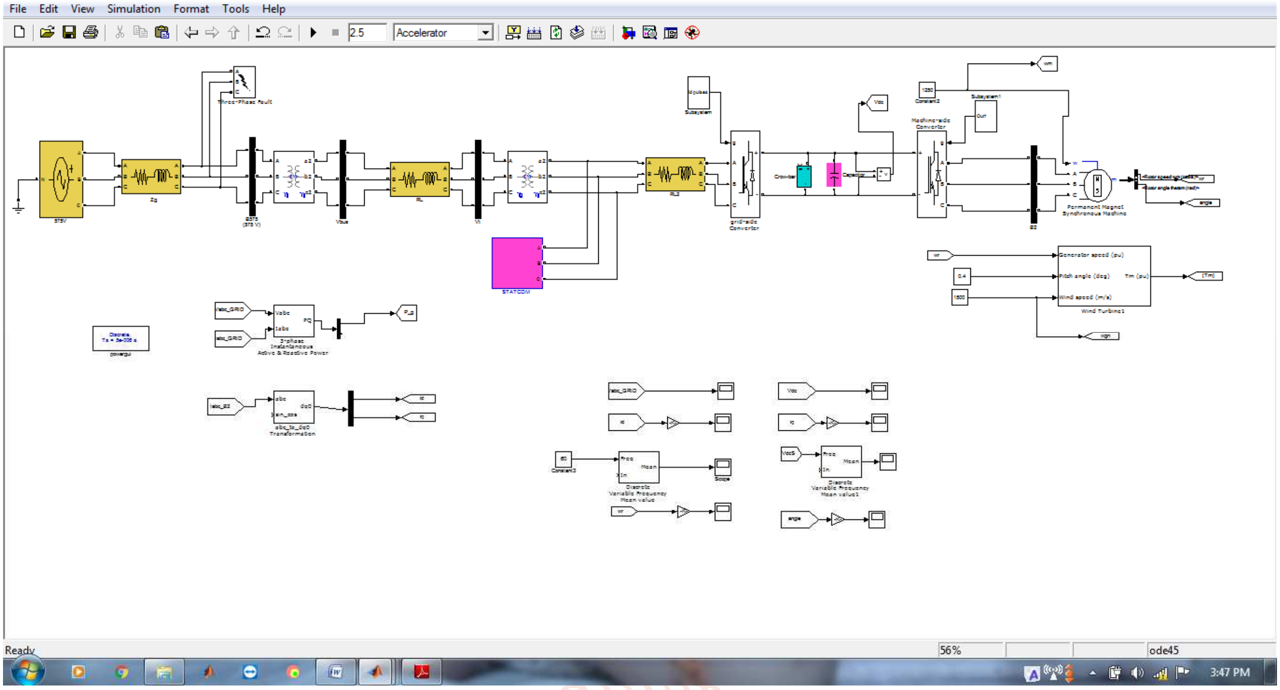

Figure 1.9: Overview.

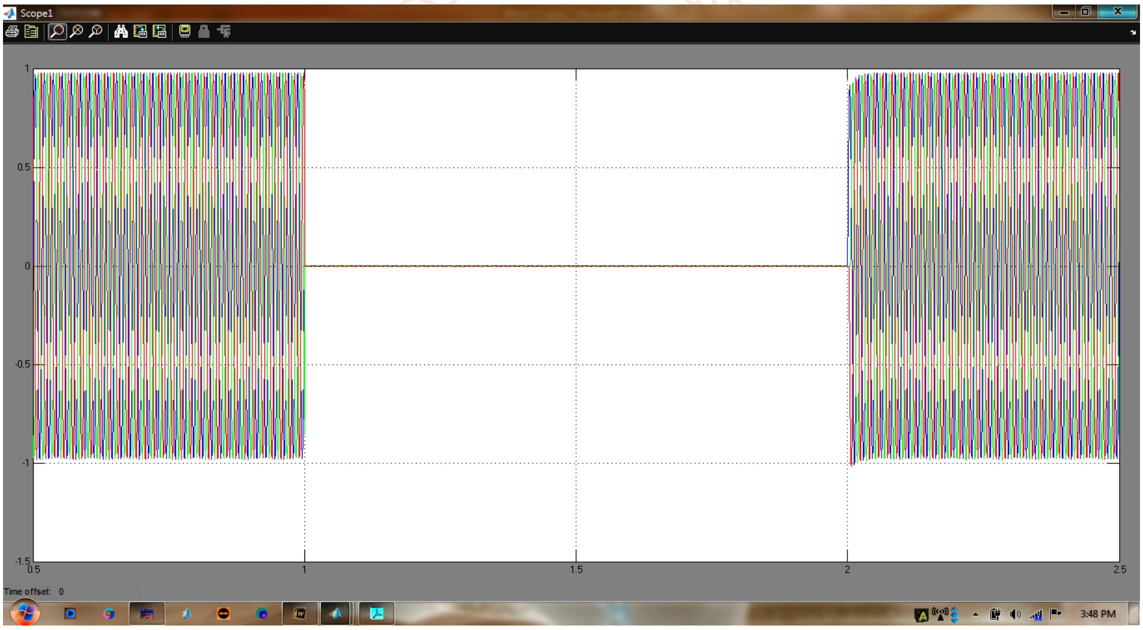

Figure 1.10: VGCP in Proposed System.

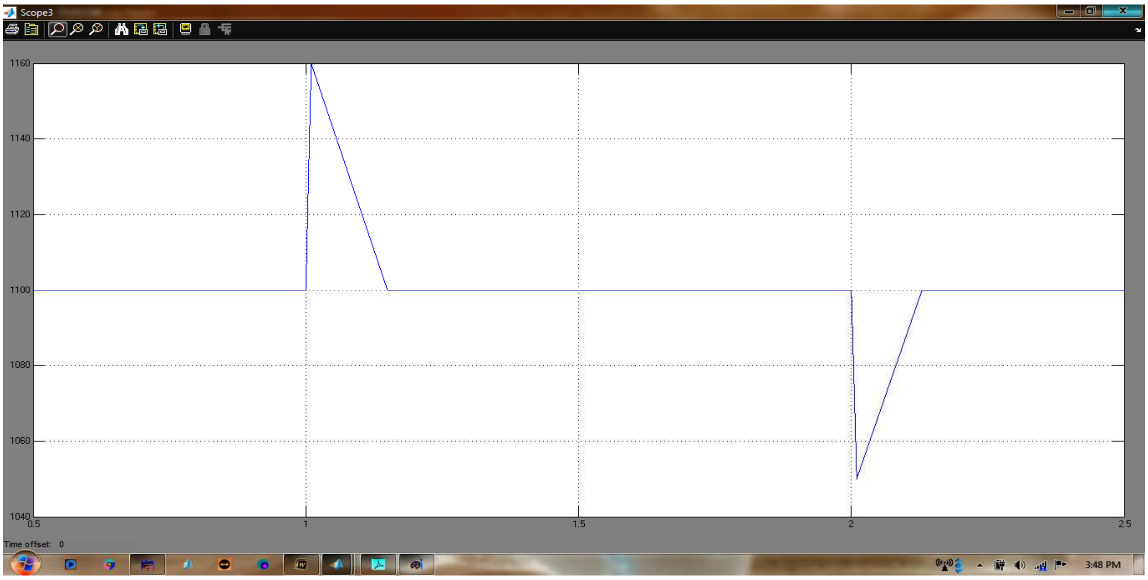

Figure 1.11: Vdc in Proposed System.

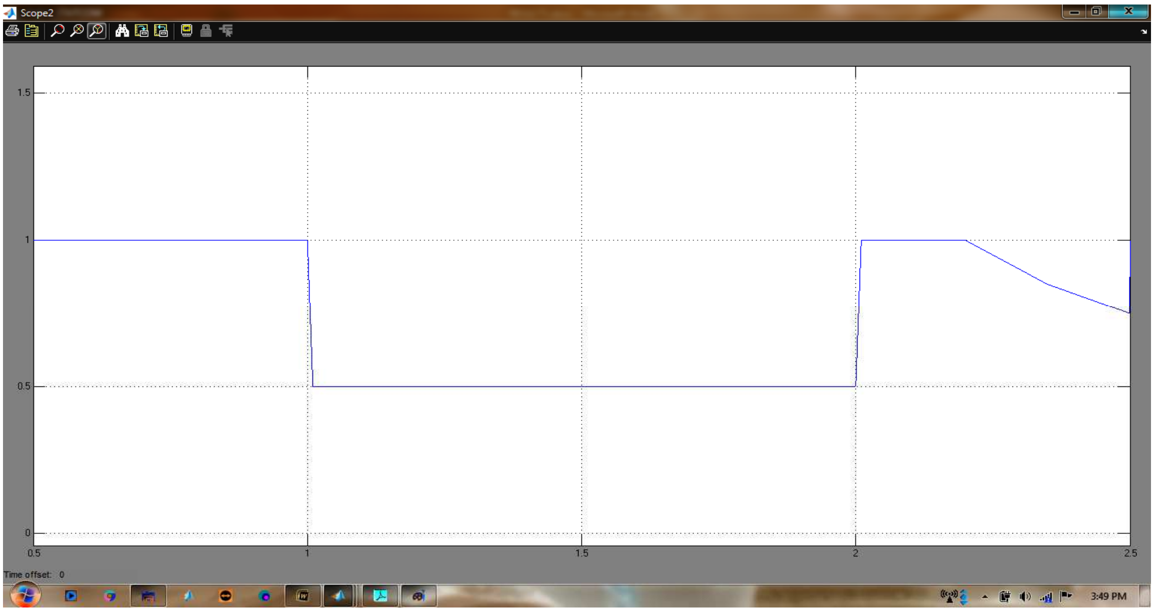

Figure 1.12: Id in Proposed System.

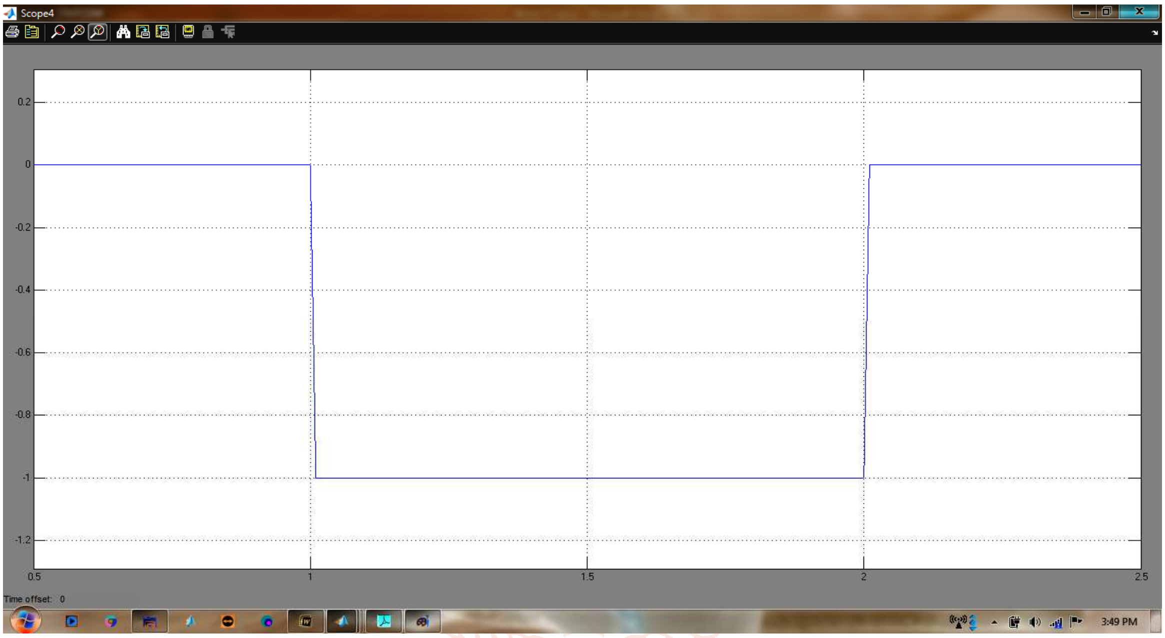

Figure 1.13: Iq Proposed System.

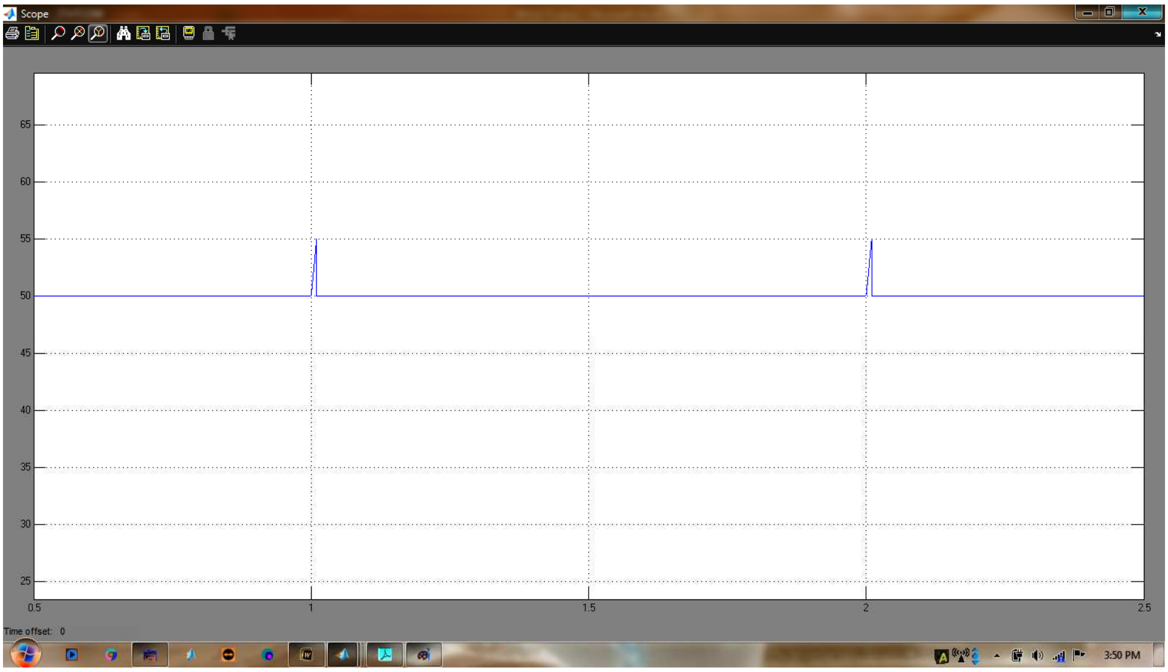

Figure 1.14: F STATCOM in Proposed System.

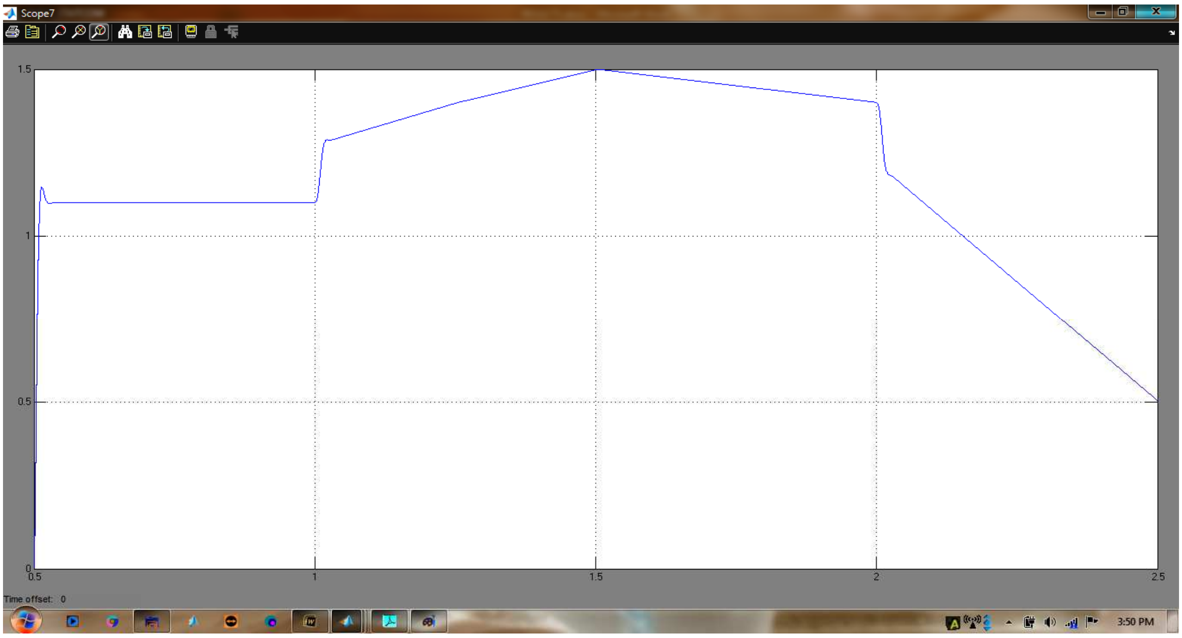

Figure 1.15: SPEED in Proposed System.

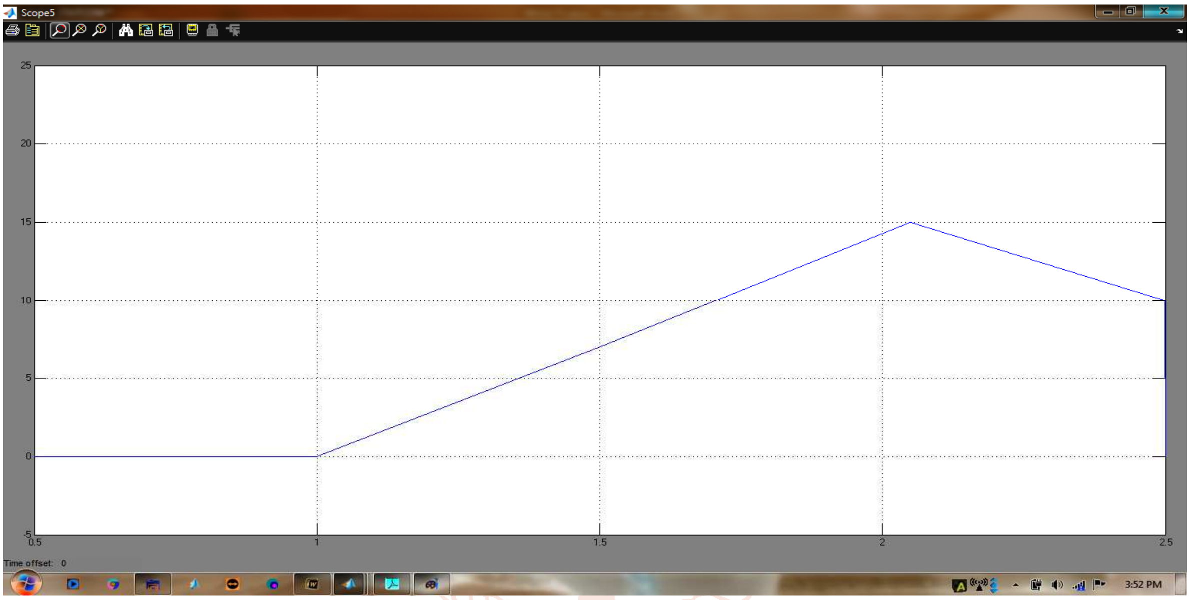

Figure 1.16: Angle in Proposed System.

V. CONCLUSION

A grid-voltage-oriented sliding mode control for DFIG is presented and tested under voltage dips. The controller has the main advantages of simple structure, no dependence on system parameters and switching of power electronic devices directly from the controller output signals.

The controller is capable to track torque and stator reactive power even under voltage distortion of the grid without sequence decomposition of rotor current nor further modification of the original controller. However, the natural stator flux component may affect stator current and active power oscillations, therefore a transient demagnetizing reference is included to the original scheme in order to eliminate natural flux component enhancing fault ride through capability of the controller. Different simulations are reported for testing the controller under balanced and unbalanced grid conditions, the results demonstrate the demagnetization strategy and the reference tracking even under unbalanced conditions, which is equivalent to negative sequence rotor current injection for compensating torque and reactive power oscillations.

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