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POWER-FLOW CONTROL AND MPPT FOR THE INTEGRATED GENERATOR-RECTIFIER SYSTEM

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Abstract: - Offshore wind is a rapidly growing renewable energy resource. Harvesting offshore energy requires multimega watt wind turbines and high efficiency, high power density, and reliable power conversion systems to achieve a competitive levelized cost of electricity. An integrated system utilizing one active and multiple passive rectifiers with a multi-port permanent magnet synchronous generator is a promising alternative for an electro-mechanical power conversion system. Deployment of the integrated systems in offshore wind energy requires maximum power point tracking (MPPT) capability, which is challenging due to the presence of numerous uncontrolled passive rectifiers. This paper shows feasibility of MPPT based on a finding that the active rectifier d-axis current can control the total system output power. The MPPT capability opens up opportunities for the integrated systems in offshore wind applications.

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I INTRODUCTION

Wind energy conversion systems have been attracting wide attention as a renewable energy source due to depleting fossil fuel reserves and environmental concerns as a direct consequence of using fossil fuel and nuclear energy sources. Wind energy, even though abundant, varies continually as wind speed changes throughout the day. The amount of power output from a wind energy conversion system (WECS) depends upon the accuracy with which the peak power points are tracked by the maximum power point tracking (MPPT) controller of the WECS control system irrespective of the type of generator used. This study provides a review of past and present MPPT controllers used for extracting maximum power from the WECS using permanent magnet synchronous generators (PMSG), squirrel cage induction generators (SCIG) and doubly fed induction generator (DFIG). These controllers can be classified into three main control methods, namely tip speed ratio (TSR) control, power signal feedback (PSF) control and hill-climb search (HCS) control. Then, main MPPT control methods are presented, after which, MPPT controllers used for extracting maximum possible power in WECS are presented.

A permanent magnet synchronous generator (PMSG)-based integrated generator-rectifier system, as shown in Fig. 1(a), is a promising alternative [20], [21]. The mechanical power on the turbine shaft is converted to ac electrical power by a multi-port PMSG. Each port is connected to either a passive or an active rectifier for ac-to-dc conversion. The dc outputs of the rectifiers are serially connected to form a relatively highvoltage dc bus. Each rectifier supports only a portion of the total dc-bus voltage. Consequently, 60% of the total power is processed on passive rectifiers, leading to a 47% reduction in conversion loss at the rated operating condition. The overall system power density and reliability improve because of the active-rectifier size reduction.

II LITERATURE SURVEY:

Offshore wind is an emerging renewable energy resource with rapidly increasing installed capacity [2]–[5]. Recently, offshore wind turbines exceeding the common land-based power output have been developed to target a competitive levelized cost of electricity (LCOE). For example, Gamesa 10X [6], Haliade X [7], and Vestas V164 [8] have power ratings ranging between ten and twelve megawatts. Development of high-power-density, efficient, and reliable electro-mechanical power conversion systems for these turbines based on conventional converter topologies is challenging. The major obstacles are limited power-electronics-switch voltage/current ratings and high switching losses [9]. Two-level PWM and neutralpoint-clamped converters are the most commonly used architectures. The former has a simple construction and a straightforward control scheme [10]–[12]. Each switch is rated for the peak ac-side current and dc-side voltage. Available power electronics devices are connected in series and/or in parallel to process the multi-megawatt power. These configurations lead to poor reliability [13]. Neutral-point-clamped topology reduces the voltage rating requirements of each switch [14]– [16]. Loss distribution is uneven across the switches, leading to early failure at the hot spots. Multi-port generators have been proposed to reduce the power rating of the individual power converters [17]–[19]. All these architectures rely solely on an active rectifier for ac to dc conversion.

III PROPOSED SYSTEM:

A permanent magnet synchronous generator (PMSG)-based integrated generator-rectifier system, as shown in Fig. 1(a), is a promising alternative. The mechanical power on the turbine shaft is converted to ac electrical power by a multi-port PMSG. Each port is connected to either a passive or an active rectifier for ac-to-dc conversion. The dc outputs of the rectifiers are serially connected to form a relatively high voltage dc bus. Each rectifier supports only a portion of the total dc-bus voltage. Consequently, 60% of the total power is processed on passive rectifiers, leading to a 47% reduction in conversion loss at the rated operating condition. The overall system power density and reliability improve because of the active-rectifier size reduction.

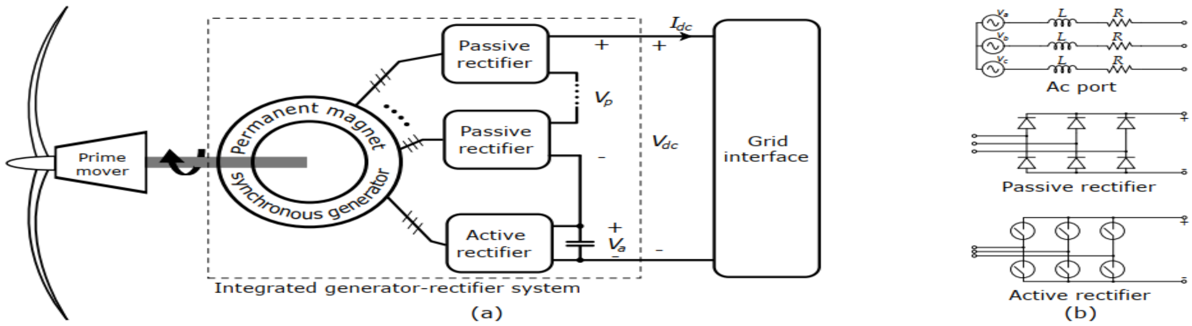


Figure 1. (a) Wind turbine power-point tracking architecture: the prime mover is a variable-speed wind turbine.

The turbine shares a common shaft with the multi-port PMSG. Ac power is converted to dc by an integrated generator-rectifier system. The dc output is connected to a stiff dc interface. The integrated generator-rectifier system performs maximum power-point tracking to extract the turbine maximum power. (b) Each phase of a three-phase ac port is modelled by a back emf source in series with generator inductance L and phase resistance R. The passive rectifier is a six-pulse diode rectifier, and the active rectifier is a three-phase two-level converter.

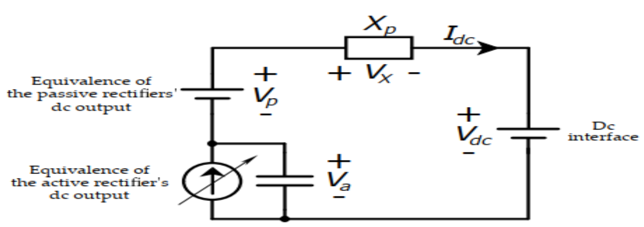


Figure 2. Simplified equivalent circuit of the integrated generator-rectifier system.

The dc output of the passive rectifiers is modeled by a voltage source. The output of the active rectifier is modeled by a controllable current source. The serial voltage and current sources are connected to a constant dc voltage representing the dc interface.

IV PROPOSED CONTROL

Power-flow control is achieved by using a cascaded architecture, as illustrated in Fig. 2. The inner loop comprises current controllers to regulate the d-axis and q-axis currents of the active rectifier. The d-axis and q-axis current control the power flow and power factor, respectively. The outer-loop power controller calculates the d-axis current command to deliver the reference power P ∗ dc to the dc bus. The power command is the output of an MPPT algorithm that uses generator rotational speed as an input. Setting the q-axis current to zero leads to a unity power-factor operation of the active rectifier.

The proposed power-control architecture is applied to track the wind turbine maximum power point. MPPT is achieved if at each generator speed, the electrical power drawn follows the maximum power curve [23]. Consider a wind turbine in Fig. 6 with Rblade = 164 m, operating at a rated wind speed of 12 m/s and an air density ρ of 1.15 kg/m3 . Figure 7 plot the mechanical power curves of the wind turbine at various wind speeds using dashed lines. The maximum power curve is formed by connecting peak values of all the mechanical power curves. Consider the operation at a wind speed of 12 m/s. The vertical line crossing the intersection between the maximum power curve and the mechanical power curve splits the graph into two regions. In the gray region, the input mechanical power to the generator is higher than the output electrical power. The generator rotational speed increases. Then, the generator enters the white region, in which the mechanical power is lower than the electrical power. The generator slows down. Eventually, the speed settles at the border of the two regions, at which point the maximum power of 10 MW is generated.

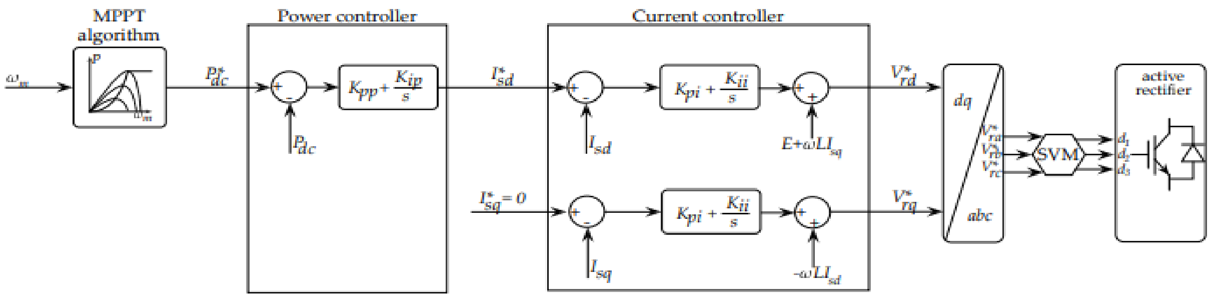
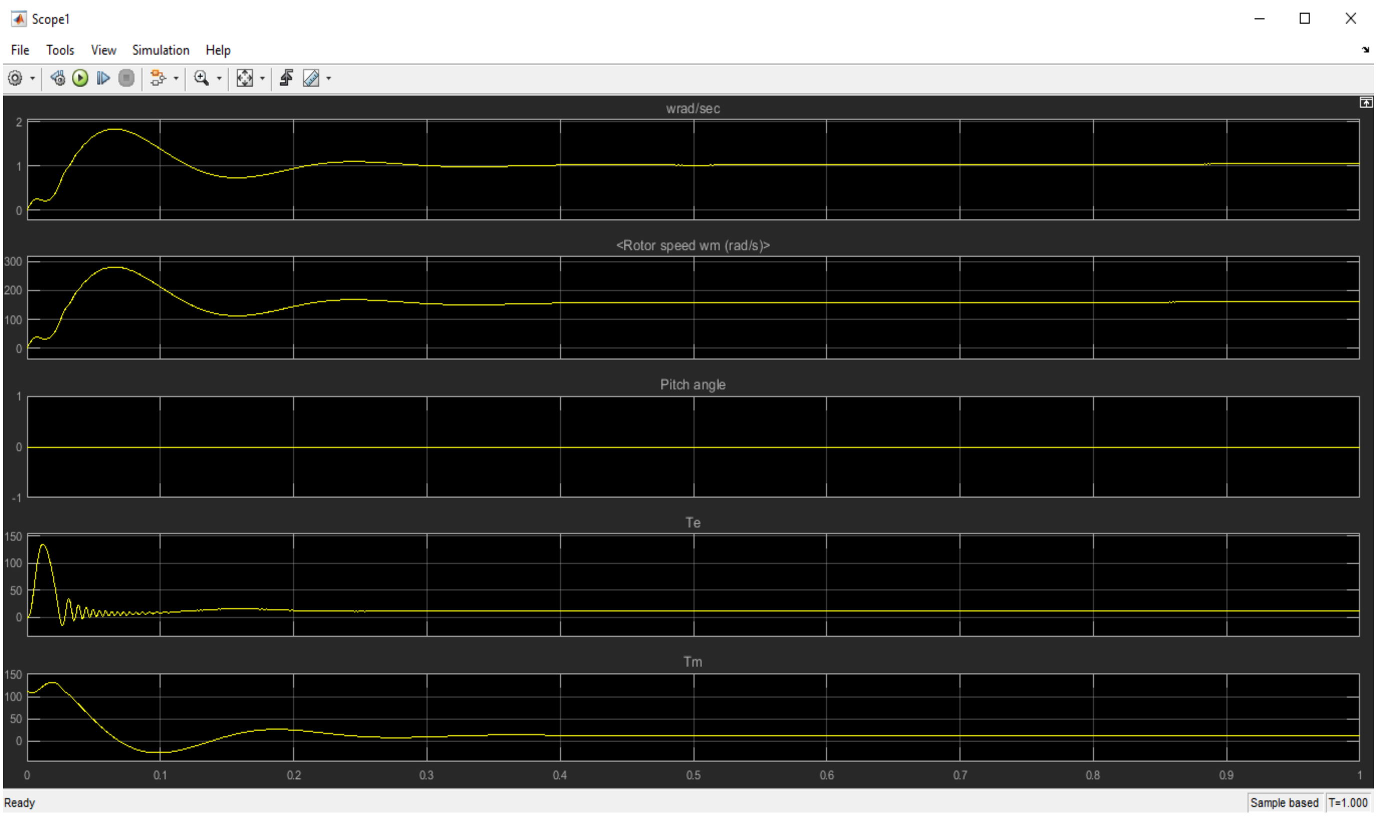
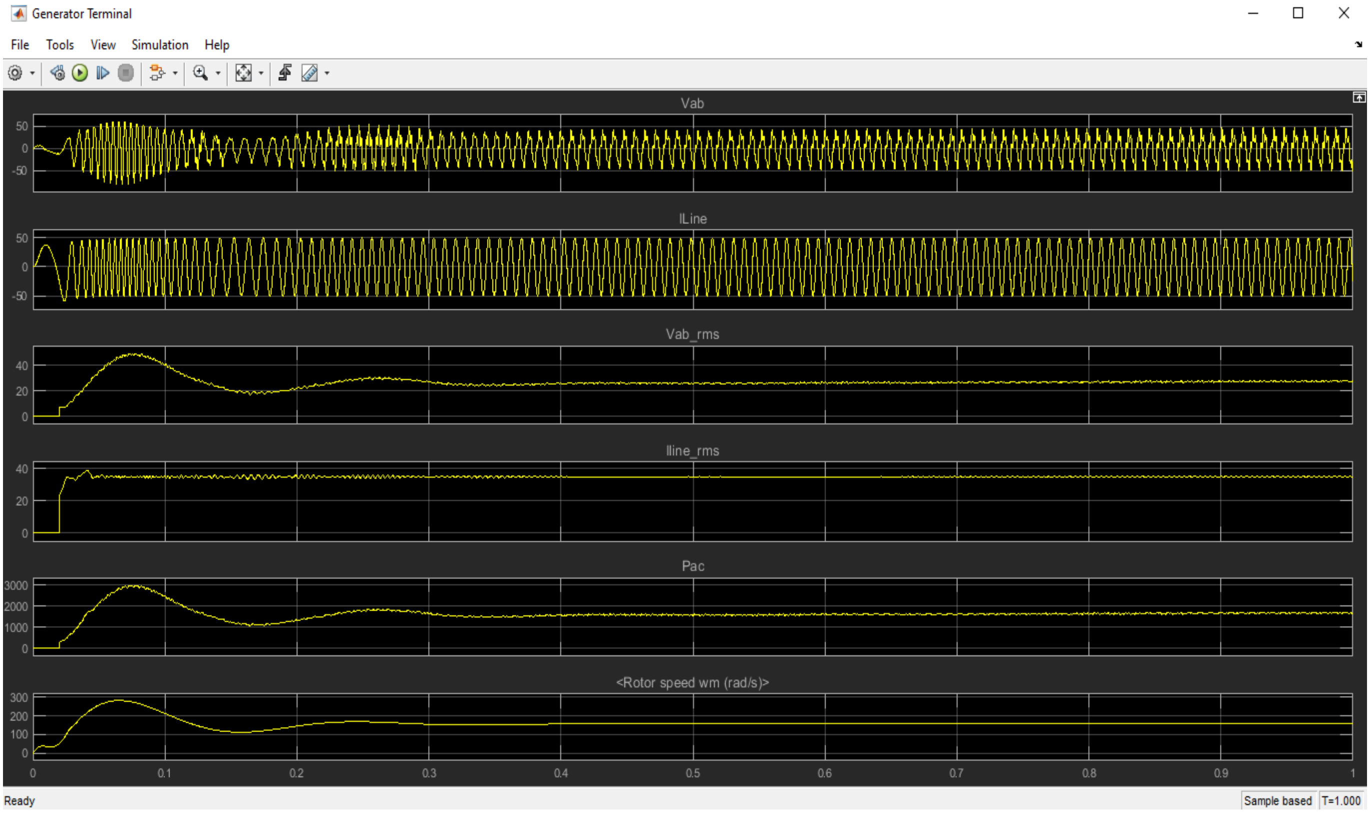


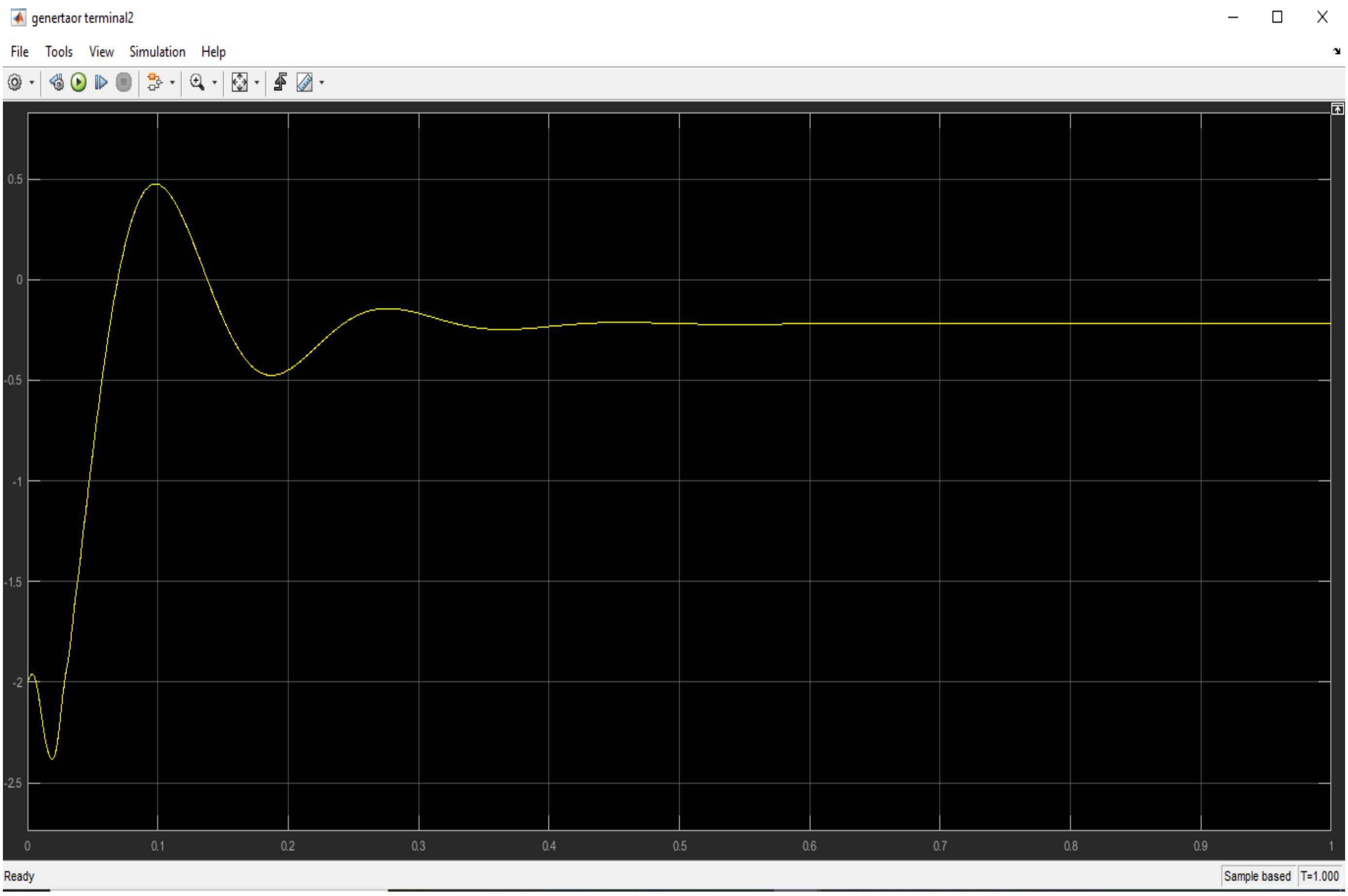
Figure 3. Cascaded architecture applied to the active rectifier to accomplish power-flow control for the entire integrated generator-rectifier system

Wind Performance



Generator Terminal





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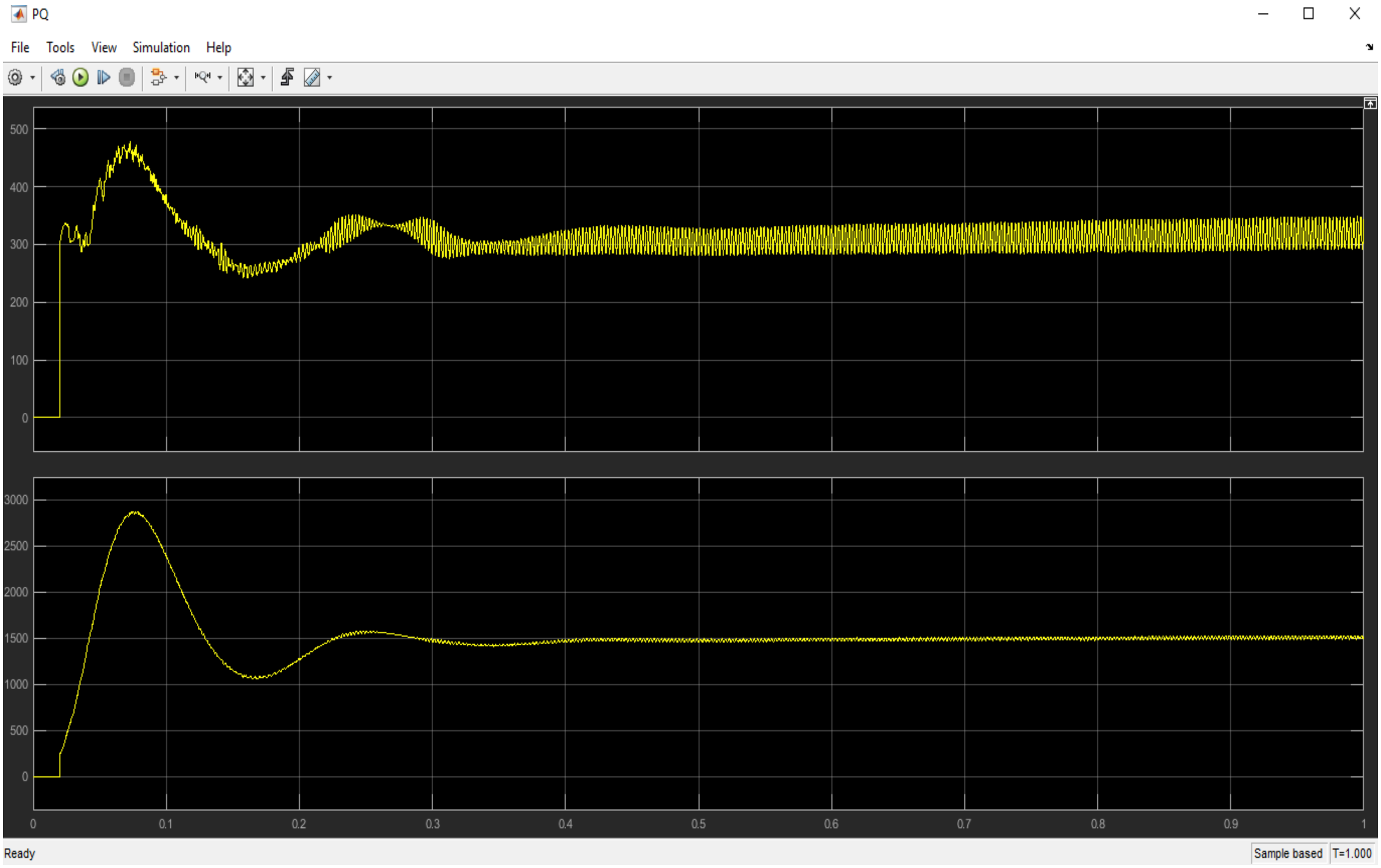
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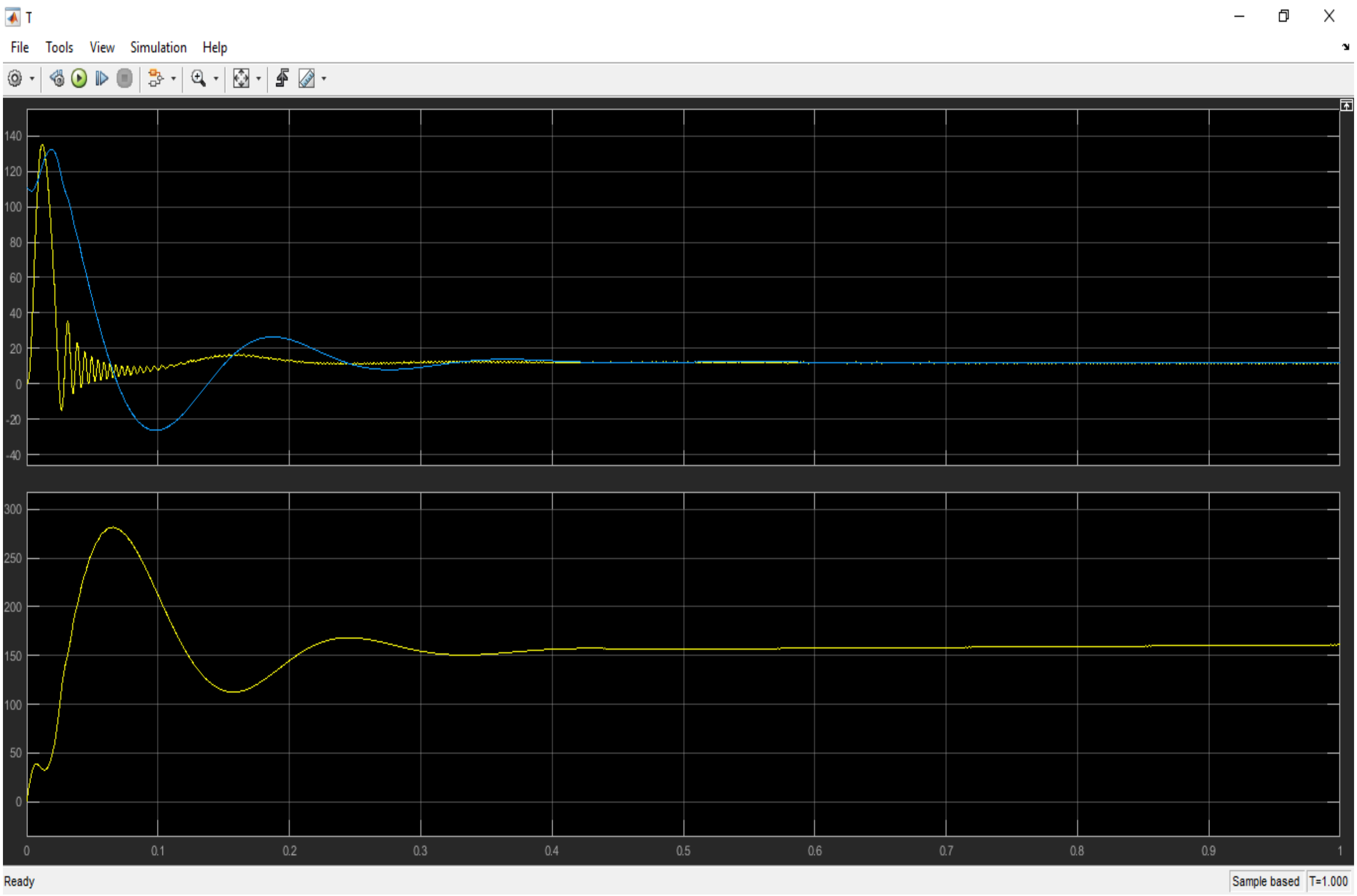
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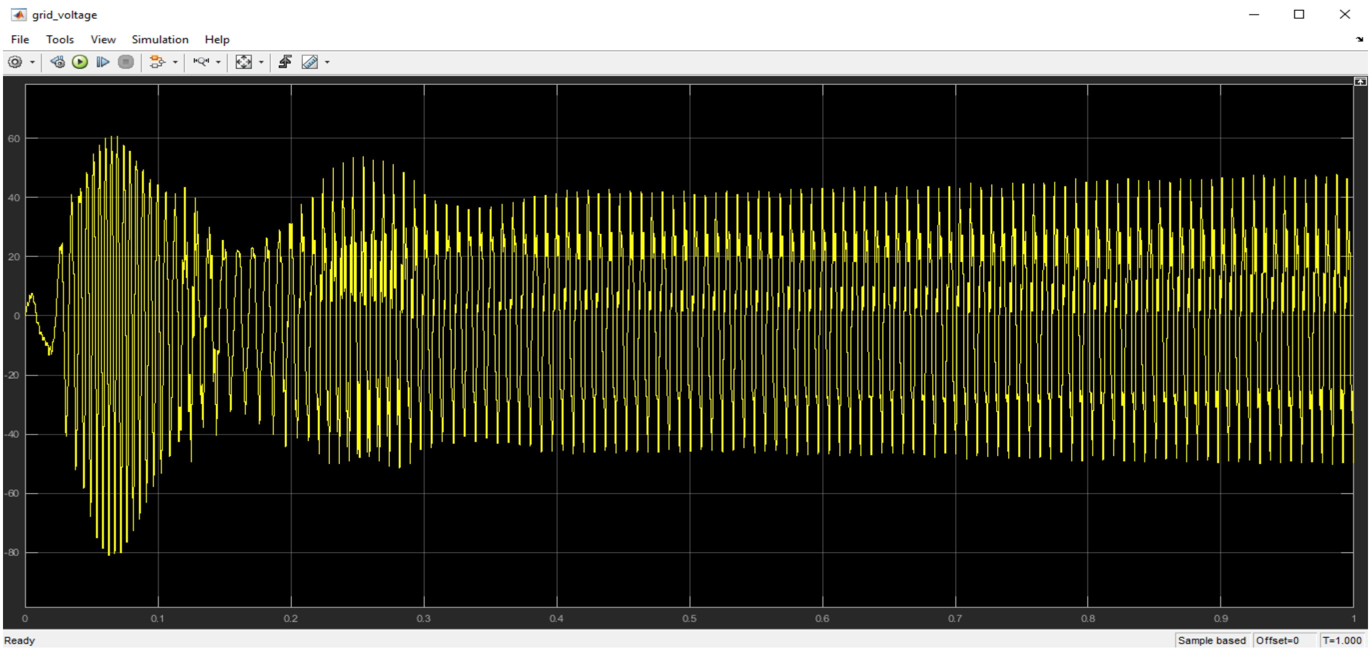
Grid Voltage



V CONCLUSION

This project presents an MPPT methodology for an integrated generator-rectifier system. An analytical relationship between the dc-bus power and the active rectifier d-axis current is established and validated using simulation. A cascaded control architecture is proposed for practical implementation. The inner loop comprises PI current controllers with feed-forward terms, while the outer loop is a PI power controller. Satisfactory power tracking performance has been accomplished. The power flow control enables the wind turbine MPPT through controlling the dc-bus power. This capability opens up opportunities for the integrated generator rectifier systems in wind energy applications.

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