Dr. Satendra Kr Singh Kushwaha

Nagpur, Maharashtra, India

+91-8840956968/9889556200

satendra0107@gmail.com/

satendra.kushwaha@raisoni.net

DOB-01 July 1989

https://www.linkedin.com/in/

satendra-kushwaha-44a01055/

OBJECTIVE

To acquire strong technical skills and experience in the organization and pursue a challenging career in a system that encourages continuous learning and creativity in the field of teaching, research and development.

EDUCATION

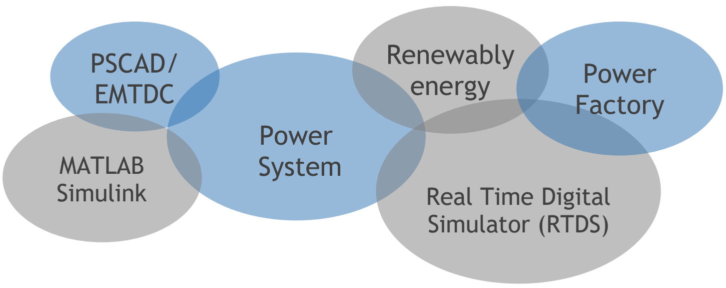
Ph.D. (Electrical Engg) (2015-2020)
(Ph. D. Awarded on 28 Dec 2020)
MNNIT Allahabad, India **[8.25/10]**
Study on some aspects of Stability and protection scheme of grid interactive Offshore Wind and Marine Current Farm

M.Tech (Power System)2013-2015
Delhi Technological University [8.05/10]
New Delhi, India
Challenges In The Grid Connection Of Marine Current Power

B.Tech (2008-2012)
Electrical Engg
Kamla Nehru Institute of technology
Sultanpur, Uttar Pradesh, India
Affiliated to AKTU(Formally, UPTU)

KEY POSITIONS & SKILLS

Student Co-ordinator** (GIAN 2017), **Volunteer in varions short term coures and International IEEE conference Events organised by Institute.



EXPERIENCE (6+ Years)

- **Assistant Professor**
  April 2021- Till Date
  Department of Electrical Engineering
  G H Raisoni Institute of Engineering and Technology, Nagpur, Maharashtra 440028
- **Senior Research Fellow**
  July 2017-July2020
  MN-NIT Allahabad, Prayagraj, U.P. India 211004

Project :

- **Project Titled: " Study on Some Aspects of Stability and Protection Scheme of Grid Interactive Offshore Wind and Marine Current Farm"**

- **Junior Research Fellow**
  July 2015 to July 2017, MNNIT Prayagraj, U.P. India 211004

Project: Modelling and Simulation of DFIG based Offshore Wind turbine

- **Teaching Assistant**
  (July2015- July2020), MNNIT Prayagraj, U.P. India 211004

Professional Memberships

GMIEEE, IEEEYPM, IEEEPES, IAENG, IEEECPM

Professional Networks Links

Google Scholar :
https://scholar.google.com/citations?hl=en&user=1MUpOfMAAAAJ
Research Gate :
https://www.researchgate.net/profile/Satendra_kushwaha
Academia :
https://mnnnit.academia.edu/Satendrakushwaha
Linked In :
https://www.linkedin.com/in/satendra-kushwaha-44a01055/
ORCID ID :
https://orcid.org/0000-0002-7385-4627

PUBLICATIONS

- SCI Journals-03
- Scopus- 01
- Book Chapters-01
- International Conferences-06

REFEREE

Prof. Paulson Samuel
Professor
Dept of Electrical Eng
MNNIT Allahabad, India
paul@mnnit.ac.in

Dr. S. R. Mohanty
Associate Professor
Dept. of Electrical Eng
IIT-BHU, Varanasi, India
soumya.eee@iitbhu.ac.in

Work Experience and Responsibilities:

- **Assistant Professor**
  April 2021- Till Date
  Department of Electrical Engineering
  G H Raisoni Institute of Engineering and Technology, Nagpur, Maharashtra 440028
  (An Autonomous Institute & NAAC Accredited with A+)

  NBA COORDINATOR and Criteria In-charge:
  Worked as an NBA Coordinator and Criteria in-charge in the EE Department and Successfully Conducted the NBA visit in our department on **14-16Jan 2022**.
  Renewable Club In-charge and R&D Coordinator:
  I am In-charge of Renewable Club in our Institute under which we organized hands on practice, Industrial visit and Webinar on renewable resources to our students. Also, I am R&D departmental coordinator in our institute.

- **Senior Research Fellow**
  July 2017-July2020
  MN-NIT Allahabad, Prayagraj, U.P. India 211004

- **Junior Research Fellow**
  July 2015-July2017
  MN-NIT Allahabad, Prayagraj, U.P. India 211004

Research Work in MNNIT ALLAHABAD

1. **Modelling and Simulation of integrated a large offshore wind farm and marine current farm and its impact on the power system stability with regard to steady-state, dynamic, and transient stability followed by possible remedial measures.**
   a. Especially developed a simulation base dynamic model of OWF and MCF with systematic representations of parametric uncertainties and develop a linear matrix inequality (LMI)-based H∞ controller with a given control strategy under parametric uncertainties to provide enough support for the improvement of system dynamic-stability after a grid disturbance or faults.
   b. Further developed a control scheme for stability assessment of grid-interactive OWF and MCF using STATCOM and BFCL under parametric uncertainties in RTDS platform.
2. **Analyzing the Impact of STATCOM and BFCL on Performance of Distance relay and its improvement by adaptive setting for Grid Interactive Offshore Wind and Marine Current Farm**.
   a. Especially developed a PSCAD/EMTDC based simulation model to analyzed the impact of dynamic impedance of STATCOM and BFCL on the performance of distance relay.
   b. Further developed an adaptive setting of distance relay to take corrective action and mitigate the adverse effect of STATCOM and BFCL on the relay operation.

List of Publication

International Journals

[1] Satendra Kr Singh Kushwaha, S. R. Mohanty and Paulson Samuel "Robust H∞ control for stability assessment in grid-connected offshore wind and marine current hybrid system," ***IET* Renewable *Power Generation***, vol. 13, no. 2, pp. 318-329, 2019.

[2] Satendra Kr Singh Kushwaha, S. R. Mohanty and Paulson Samuel "Impact of STATCOM and BFCL on Performance of Distance relay and its improvement by adaptive setting for Grid Interactive Offshore Wind and Marine Current Farm***" IET Generation, Transmission & Distribution,*** vol. 14, no. 23, pp. 5547 – 5557, 2020.

[3] Satendra Kr Singh Kushwaha, S. R. Mohanty and Paulson Samuel "Stability Assessment and robust controller design of Grid Interactive Offshore Wind Farm and Marine Current Farm with STATCOM and BFCL" ***Automatika***, Vol. 62, no. 2, 197–209, 2021 DOI:10.1080/00051144.2020.1860377

[4] D. R. Karthik, B. Mallikarjuna Reddy, Satendra Kr Singh Kushwaha and Akbar Ahmed "Application of FPGA Controller in Multidevice Interleaved DC/DC Boost Converter for Air Craft Electrical Systems" ***Indian Journal of Science and Technology***, Vol. 9, no. 44, pp. 1-7, 2016

Book Chapter

[5] Satendra Kr Singh Kushwaha, S. R. Mohanty and Paulson Samuel "Stability analysis of an offshore wind and marine current farm in grid connected mode using SMES" *Intelligent Computing Techniques for Smart Energy Systems, Lecture Notes in Electrical Engineering, Springer,* vol 607, Dec. 2019.

International Conferences

[6] Satendra Kr Singh Kushwaha, S. R. Mohanty and Paulson Samuel, "Stability Assessment and Robust Controller Design of Grid Interactive Offshore Wind Farm and Marine Current Farm using STATCOM," *IEEE International Conference on Energy, Systems and Information Processing (ICESIP)*, Chennai, India, 2019, pp. 1-6, 2019.

[7] Satendra Kr Singh Kushwaha, S. R. Mohanty and Paulson Samuel, "Non-linear H-infinity Control for Grid-interactive Offshore Wind Farm and Marine Current Farm," *IEEE International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES)*, Delhi, India, pp. 420-425, 2018.

[8] Satendra Kr Singh Kushwaha, Paulson Samuel and S. R. Mohanty "Transient Stability Analysis of SCIG based Marine Current Farm and Doubly Fed Induction Generator based offshore wind farm using Bridge Type Fault Current Limiter" *IEEE Uttar Pradesh Section International Conference on Electrical, Computer and Electronics, Mathura*, pp. 494-499, 2017.

[9] K. Sekhar, S. K. S. Kushwaha, D. R. Karthik, V. M. Reddy and B. M. Reddy "Transient stability analysis of large-scale grid integration of offshore wind and marine current farm connected to grid using STATCOM," *Innovations in Power and Advanced Computing Technologies (I-PACT)*, Vellore, pp. 1-6, 2017.

[10] D. R. Karthik, B. M. Reddy and S. K. S. Kushwaha, "A PSCAD simulation on integration of multi-level converters with DC-DC converter for AC drive applications," *International Conference on Circuit, Power and Computing Technologies (ICCPCT)*, Nagercoil, 2016, pp. 1-6

[11] S. K. S. Kushwaha and S. T. Nagarajan, "Stability analysis of off shore marine current farm connected to grid," IEEE International Conference on Technological Advancements in Power and Energy (TAP Energy), Kollam, 2015, pp. 466-471, 2015.

Workshop & STTP Attended

[1] Networked and Embedded Control of Energy & Systems, October 14-15, 2016 EED MNNIT Allahabad 2016

[2] Photovoltaics: Technology and Business Overview, March 04-06, 2017 Physics and EED, MNNIT Allahabad 2017

[3] Advances in Power Electronics and Renewable Energy Resources, 21-23 July, 2017 EED MNNIT Allahabad 2017

[4] Golbal Initiative of Academic Networks (GIAN) on "Power System Voly/VAR Control and Voltage Stability" during 26-30 December, 2017 in the Department of electrical engineering, MNNIT Allahabad, India

[5] Modelling and Simulation of renewabble energy systems, May 28- June 3, 2018 EED, MNNIT Allahabad 2018.

[6] UNPACKING E-MOBILITY TECHNOLOGIES FOR INDIA, November 20 - 24, 2021 MNNIT Allahabad 2021.

I hereby declare that the information provided above is correct to the best of my knowledge

Date **:** Jan. 2022
Place **:** Nagpur, Maharashtra INDIA **Satendra Kr Singh Kushwaha**

IET Renewable Power Generation

Research Article

ISSN 1752-1416
Received on 21st May 2018
Revised 29th September 2018
Accepted on 31st October 2018
E-First on 6th December 2018
doi: 10.1049/iet-rpg.2018.5304
www.ietdl.org

Robust H∞ control for stability assessment in grid-connected offshore wind and marine current hybrid system

Satendra Kumar Singh Kushwaha[1], *Soumya R. Mohanty*[2] ✉, *Paulson Samuel*[1]
[1]*Department of Electrical Engineering, MNNIT Allahabad, Allahabad 211004, India*
[2]*Department of Electrical Engineering, IIT-BHU, Varanasi 221005, India*
✉ *E-mail: Soumya@mnnit.ac.in*

Abstract: The geographic suitability brings the offshore wind farm (OWF) and marine current farm (MCF) together with their aggregated power fed to grid simultaneously in most relevant energy harnessing infrastructures. However, stability assessment of the integrated system is a major concern due to the integration of stochastic and intermittent sources with parametric uncertainty. Bridge-type fault current limiter (BFCL) has consolidated their application for a suitable enhancement of stability margin for most modern supply systems. In this article, a detailed modelling of the integrated system is carried out in the presence of BFCL along with consideration of uncertainty as well. A robust H∞ controller design strategy for stability assessment of grid-connected OWF and MCF in the presence of parametric uncertainties is presented in this article. Linear matrix inequality (LMI) conditions are derived in the context of evaluating the robust controller gain with respect to desired robust stability margin. The efficacy of the controller design is compared with that of H∞ loop shaping and conventional P-I control through different case studies with simulation followed by real-time digital simulator (RTDS) validation.

Nomenclature

ω_{tw}, ω_{tmt}	angular velocity of the wind turbine and marine current turbine
ρ_w, ρ_m	density of wind and marine current, respectively
λ_{dqos}, λ'_{dqor}	flux linkage of stator and rotor, respectively
J_{mct}	moment of inertia of the marine current turbine
T_{m}, T_{eo}	mechanical and electrical output torque of generator
$C_{\mathrm{pw}}(\lambda_w, \beta_w)$	power coefficient of offshore wind turbine
$C_{p\_\mathrm{mct}}(\lambda_{\mathrm{mc}}, \beta_{\mathrm{mt}})$	power coefficient of marine current turbine
R_{rw}, R_{mct}	radius of wind and marine current turbine
ω_{ref}, ω_r	reference and rotor angular speed of DFIG
i_{dqos}, i'_{dqor}	stator and rotor current of SCIG in d–q frame of reference, respectively
i_s, i_r	stator and rotor current of DFIG
r_s, r_r	stator and rotor resistance of DFIG
v_s, v_r	stator and rotor voltage of DFIG
ψ_s, ψ_r	stator and rotor linkage flux of DFIG
V_{dqos}	terminal voltage of SCIG in d–q frame of reference
V_w, V_m	velocity of wind and marine current

1 Introduction

In recent years, research on alternate resources has gained momentum mostly as a fall out of rising world temperature and depleting fossil fuels. The intention is to address amicably the trade-off between rising power demand worldwide and concerns for green environment. The ocean has huge untapped energy resource in the form of offshore wind, tidal wave, geothermal energy etc. available relatively easily at different geographical locations. Extracting the offshore wind and oceanic current energy has the potential to meet our future energy needs to a large extent. Currently, both offshore wind and ocean energy has been combined together in the UK [1]. The grid integration of the offshore wind farm (OWF) and marine current farm (MCF) raises some serious challenges in regard to grid code requirement [2, 3], power quality, grid stability [4, 5], and fault ride through capability [6]. The process will augment nicely by using a robust control technique to deal with the stochastic nature of wind and marine current speed, non-linear plant dynamics, and the presence of parameter uncertainties.

Doubly fed induction generators (DFIGs) are generally used in OWF with the merits of independent active and reactive power control, small size, lower cost, and wide range of operating speed. Voltage fluctuations and unbalance loading cause series of problems to DFIG, such as overheating of generator winding with unbalance currents, change of flux density, and saturation effects [7]. Parameter uncertainty is another challenge for controller design of DFIG [8]. It affects the controller performance, stability, and reliability of the system. Various current control techniques have been developed to address the voltage fluctuation, steady-state stability, and transient stability of the system. The common use of control strategy is to add more regulators to the existing proportional integral (PI) controller. Some typical control strategies are PI plus resonant (PIR) control, dual current control, and proportional plus resonant (PR) control [9–11]. The simplest control strategies are based on single-input, single-output (SISO) control theory and require the generator model to be the simplified to first-order nominal model of DFIG. They achieve good performance as nominal model and may give satisfactory performance if the parameter uncertainty is not considered. However, the robust performance for all possible uncertainty in system parameter is not guaranteed. There are two approaches which allow the uncertainty in OWF and disturbance: adaptive and robust control. The adaptive control estimates the parameter and calculates the controller accordingly, but it involves online design and is computationally intensive. The second approach is to incorporate the uncertainty tolerances in the design of the controller and make it immune to the uncertainty in the parameter and disturbance. Such schemes are fuzzy logic control [12, 13], sliding mode control [14, 15], and predictive direct power control [16, 17]. However, the parametric uncertainty robustness is not fully achievable through these methods. The H∞ robust control is a multi-input, multi-output (MIMO) structure where the system stability and robust performance can be guaranteed by H∞ norms to consider all possible uncertainties into a bound [18, 19]. An H∞ controller design is proposed in this paper to improve robustness in the presence of perturbation due to parametric uncertainty and or high stochastic wind speed.

IET Generation, Transmission & Distribution

Research Article

Impact of STATCOM and BFCL on the performance of distance relay and its improvement by adaptive setting for grid-interactive offshore wind and marine current farm

ISSN 1751-8687
Received on 24th April 2020
Revised 23rd August 2020
Accepted on 28th August 2020
doi: 10.1049/iet-gtd.2020.0775
www.ietdl.org

Satendra Kumar Singh Kushwaha[1] ✉, *Soumya Ranjan Mohanty*[2], *Paulson Samuel*[1]

[1]*Department of Electrical Engineering, MNNIT Allahabad, Prayagraj 211004, India*

[2]*Department of Electrical Engineering, IIT-BHU, Varanasi 221005, India*

✉ *E-mail: ree1506@mnnit.ac.in*

Abstract: This study explores the impact of the dynamic impedance of static synchronous compensator (STATCOM) and bridge type fault current limiter (BFCL) on the performance of distance relay and its improvement by adaptive setting for Grid Interactive Offshore Wind and Marine-Current Farm. For assessments, analytical results are presented under different STATCOM settings, low voltage ride through (LVRT) condition, and different types of fault conditions. Moreover, the presence of STATCOM and BFCL significantly changes the apparent impedance characteristic of the studied system. It is also seen that the presence of STATCOM likely to induce an under reach and overreach problem of distance relay. Further, the LVRT capability is significantly affected as STATCOM supplies reactive power to offshore wind generators during a short circuit on the grid side. It is found that the grid integration of OWF and MCF with STATCOM and BFCL is likely to induce mis-coordination and subsequently deteriorate the performance of distance relay, leading to system security problems. Therefore, this study proposed an adaptive setting in order to eliminate the simultaneous influence upon the dynamic impedance due to incorporation of STATCOM and BFCL on the distance relay setting. The simulation results show the efficacy of the proposed adaptive setting.

Nomenclature

v_s, v_r	stator and rotor voltages of DFIG
r_s, r_r	stator and rotor resistances of DFIG
i_s, i_r	stator and rotor currents of DFIG
ψ_s, ψ_r	stator and rotor linkage fluxes of DFIG
ω_{ref}, ω_r	reference and rotor angular speed of DFIG
V_{dqs}	terminal voltage of SCIG
i_{dqos}, i'_{dqor}	stator and rotor currents of SCIG
$\lambda_{dqos}, \lambda'_{dqor}$	flux linkage of stator and rotor
$I^1_{TL1}, I^2_{TL1}, I^0_{TL1}$	positive, negative and zero sequence current of transmission line
$I^1_{sh}, I^2_{sh}, I^0_{sh}$	positive, negative and zero sequence current of STATCOM
I_f	fault current
I_{sta}	STATCOM current
$V^1_{R1}, V^2_{R1}, V^0_{R1}$	positive, negative and zero sequence voltage at relay terminal
$I^1_{R1}, I^2_{R1}, I^0_{R1}$	positive, negative and zero sequence current of distance relay
Z_{bfcl}	apparent impedance of BFCL
Z_{R1}	apparent impedance is seen by the distance relay
Z_{owf}, Z_{mcf}, Z_g	equivalent impedances of OWF, MCF and grid
$E_{owf}, E_{mcf}, V_{grid}$	equivalent terminal voltages of OWF, MCF and grid

1 Introduction

In recent decades, the participation of renewable resources in electricity generation is rapidly increased due to higher demand for electricity day by day and limited availability of conventional resources. In particular, offshore wind farm (OWF) and marine current farms (MCFs) are attached to the distribution network and national grid in many countries [1]. The number of wind turbine integration and energy penetration in the power system is steadily increased and plays a major contribution to energy sharing and energy balance. Incorporation of wind and marine energy resource into the national grid entails several new challenges regarding power system stability and protection. The installation of flexible alternating current transmission system (FACTS) devices and fault current limiters (FCLs) enhanced the low voltage ride through (LVRT) capability, voltage stability and reactive power support and the expected increase of power demand [2, 3]. It also enhanced the overall stability and power oscillation damping by regulating the active and reactive power flow of an integrated system. Apart from the stability issues, protection issues pose challenges in the grid integration of renewables [4]. In the context of enhancement of the LVRT capability, reactive power compensation, the performance of the protective relays gets affected [5]. The distance relay is one of the key protective devices deployed at the point of common coupling (PCC) with respect to interconnection of renewables and the rest of the power network. Thus, it ought to investigate the impact of FACTS controllers and FCLs on the performance of the distance relay followed by possible remedial measures in order to enhance the dependability and security of the grid.

Several works of literature reported the impact of the FACTS controller on distance protection strategies and possible remedial measures. The work done in [6, 7] evaluated the impact of shunt FACTS parameters and its location on the performance of distance relay and its tripping boundaries. In [8], Ghorbani *et al.* investigated the impact of static VAR compensator (SVC) on the operation of impedance-based protection relay under steady-state and fault conditions. The authors in [9, 10] presented the impact of the VSC-based FACTS controller on the distance relay. The work in [11, 12] discussed the apparent impedance calculation of transmission line consisting of a unified power flow controller and evaluated the impact of mode of operation and its control parameters on relay operation. In [13], an adaptive protection scheme is proposed to improve the performance of a shunt compensated line connecting wind farm. In [14], Singh *et al.* proposed a digital impedance pilot relaying scheme for a shunt

AUTOMATIKA
https://doi.org/10.1080/00051144.2020.1860377

Stability assessment and robust controller design of grid interactive offshore wind farm and marine current farm with STATCOM and BFCL

Satendra Kumar Singh Kushwaha [a], Soumya R. Mohanty [b] and Paulson Samuel [a]

[a]Department of Electrical Engineering, Motilal Nehru National Institute of Technology Allahabad, Prayagraj, India; [b]Department of Electrical Engineering, IIT-BHU, Varanasi, India

ABSTRACT

In the context of larger renewable energy harnessing, combining offshore wind farm (OWF) and marine current farm (MCF) at the same location is often found suitable in terms of geographical conditions and economic reasons. However, stochastic nature of wind speed and marine current speed with increased penetration level significantly affects the system stability, grid voltage and raises some control and stability problem; furthermore, the parametric uncertainty of generators brings additional challenges under grid voltage distortion. Therefore, in this article, we present a consolidated application of STATCOM and BFCL in the context of stability assessment of integrated system. Consequently, a robust H∞ loop-shaping controller has been proposed in the presence of parametric uncertainties. In this context, optimizing controller performance with respect to the undesired parametric uncertainties and external disturbances has been proposed. The control effort is initiated by formulating the robust H∞ loop-shaping controller in the context of evaluating the controller parameters and gain with respect to desired robust stability margin. The efficacy of the proposed control scheme is measured through different case studies in real time digital simulation (RTDS) environment. The comparative analysis of simulation results demonstrates the effectiveness of the proposed control strategy in the context of integrated system stability and reliability.

ARTICLE HISTORY
Received 18 October 2019
Accepted 3 November 2020

KEYWORDS
Offshore wind farm; marine current farm; STATCOM; BFCL; real time digital simulation (RTDS)

1. Introduction

The remarkable growth of power demand worldwide and concerns for protection of environment have renewed interest in large-scale investments in non-conventional energy options. In the last couple of years, OWF has been found attractive as an energy solution and is being considered as an alternate resource for considerable electricity generation. The ocean has untapped energy resources in the form of tidal wave [1], geothermal, offshore wind etc. at different geographical locations. They form formidable energy resources especially in the Gulf Stream, Florida straight and California straight which is capable of making up for a large share of the future energy needs. OWF combined with MCF, owing to their natural availability in close proximity, would become a new kind of integrated energy generation system in near future. Further high correlation between offshore wind energy and marine current energy operating characteristic is arguably convenient of grid integration without raising much ancillary issues to address. However, the wind energy and marine current energy resources are stochastic in nature. Thus, high penetrations of OWF and MCF into the national grid rise some critical issues of stability [2,3] power quality and fault ride through the ability of the integrated system and the grid code requirement [4,5] takes a nose dive to take care of such issues.

One of the simple methods of running an OWF is to aggregate several doubly fed induction generator (DFIG)-based generator driven by offshore wind turbine and then connected to on-shore grid through step-up transformers and under-sea cables. Similarly, to run a marine current farm (MCF), we may use an aggregated model of squirrel cage induction generator (SCIG)-based generator driven by marine current turbine, directly connected to the grid through step-up transformers and under-sea cables. Both WTs and MCTs have similar operating characteristic, but SCIG required reactive power for magnetization, while DFIG operates close to unity with the control of back to back PWM converters. The active power generated by an SCIG-based MCF is varied because the stochastic nature of marine current speed, the absorbed reactive power and terminal voltage are significantly affected. These generators are very sensitive to the voltage distortion, e.g. grid faults, when connecting large-scale high capacity OWF and MCF to the power grid a fact device or a control device is required to compensate the power fluctuations and grid voltage distortion under dynamic

CONTACT Satendra Kumar Singh Kushwaha ree1506@mnnit.ac.in Department of Electrical Engineering, Motilal Nehru National Institute of Technology Allahabad, Prayagraj 211004, India.