Ph.D. Registration Seminar

on

Vulnerability and Robustness of Wind Integrated Power Systems

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Introduction

- Concept of sustainable development
- Kyoto Protocol (1997), Paris Agreement (2015) – Intended Nationally Determined Contributions
- Clean Development Mechanism: financial assistance to RES projects linked to cost and emission additionality
- Baseline refers to the business-as-usual (BAU) scenario, that is, when the project is not implemented
- Wind energy is the fastest growing RES.
    - Wind power scenario generation
    - Optimal operation
    - Network constraints
- Dichotomy between wind project development and power system operation

Limitations of the existing literature

- Benefits of wind integration are not properly quantified especially in terms of **cost savings** and **emission reduction**.
- No comprehensive research work investigating impact wind generation on **capacity factor** of existing generators.
- In the work related to OPF, the **variation of turbine characteristics** are not considered.
- A comprehensive investigation into the **benefits of wind integration** within the context of EED and OPF is not yet attempted.
- A **composite index** to numerically establish the impact of wind integration in terms of cost savings, emission reduction, network losses and capacity factor is not yet attempted.

Objectives of the Work

1. To investigate the relevant methodologies for wind resource assessment and wind power scenario generation and hence select the most appropriate technique to model wind power for inclusion in power system operation.
2. To compute the cost savings and emission reduction capability of wind power when incorporated in the economic emission scheduling of power systems and therefore to evaluate the impacts of generator fuel cost, emission characteristics and the types of solution on CS and ER.
3. To integrate wind power scenarios in the optimal power flow model so as to assess the impact of wind integration on a number of well accepted objectives of OPF i.e. generation cost, emission, real power loss, reactive power loss and voltage deviation.
4. To assess the influence of the power system on the benefits of wind energy such as cost savings and emission reduction by formulating the above mentioned benefits as additionality of wind energy projects.
5. To assess the impact of wind integration on power system in terms of a composite index that is formulated on issues of system operation. The said index can provide a comprehensive quantitative measure of the impact of inclusion of wind energy in power systems.

Optimization Techniques and Software

- Focus is not to propose any new optimization technique
- Optimum solution need not be global
- MATLAB Optimization Toolbox (fmincon, fgoalattain)
- A comparison with state-of-the art validates the selected techniques
- Matpower5.1 for Optimal Power Flow
- MATLAB Statistics Toolbox (fitdist, mle, copularnd)

Overview of Chapters

1. **Chapter-1** provides **literature review** and discuss the context of the proposed work.
2. **Chapter-2** discusses the methodologies for **wind power** scenario generation.
3. **Chapter-3** investigates the impact of wind integration in **economic emission scheduling**.
4. **Chapter-4** performs **probabilistic OPF** using simulation method and investigates the impact of variation in turbine parameters and wind speed correlation.
5. **Chapter-5** redefines the benefits the wind integration as **additionality** of wind farms and investigates the impact of integration in power systems on additionality.
6. **Chapter-6** proposes a **composite index** in terms of a distance metric comprising of cost, emission, losses and capacity factor.
7. **Chapter-7** will summarize the results of the work and provide the contour for future scope.

Equation Example

1. Weibull distribution

$$f(v) = k\frac{v^{k-1}}{c^k}\exp\left(-\left(\frac{v}{c}\right)^k\right) \tag{1}$$

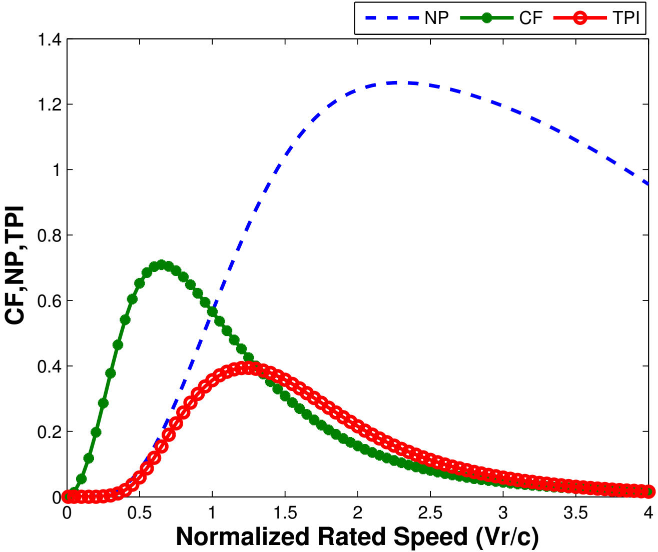
$$F(v) = 1 - \exp\left(-\left(\frac{v}{c}\right)^k\right) \tag{2}$$

2. Gamma distribution

$$g(v) = \frac{1}{b^a\Gamma(a)}v^{a-1}exp(-v/b) \tag{3}$$

$$G(v) = \int \frac{v^{a-1}}{b^a\Gamma(a)}exp(-v/b)dv \tag{4}$$

Figure Example

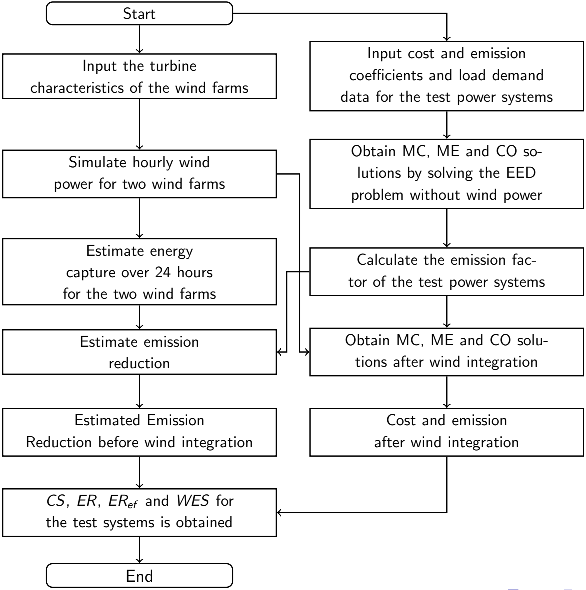


Example of Table

Height	10m	30m	50m	80m	100m
WPD (W/m^2)	219.44	556.01	781.76	1029.64	1160.72

Method	k	c	χ^2
LQ	1.84	7.35	252.16
MLE	2.01	8.02	17.09
mMLE	2.02	8.02	18.06
AM	2.03	8.02	21.25
RM	2.25	9.04	608.57
CM	2.31	9.94	1796.07
WEP	2.01	8.02	17.4

Solution Methodology



Another Example of Equations

$$P = P_s + P_r = v_{ds} i_{ds} + v_{qs} i_{qs} + v_{dr} i_{dr} + v_{qr} i_{qr} \tag{5}$$

$$Q = Q_s + Q_r = v_{qs} i_{ds} - v_{ds} i_{qs} + v_{qr} i_{dr} - v_{dr} i_{qr} \tag{6}$$

$$v_{ds} = -R_s i_{ds} + \omega_s[(L_s + L_m) i_{qs} + L_m i_{qr}] \tag{7}$$

$$v_{qs} = -R_s i_{qs} - \omega_s[(L_s + L_m) i_{ds} + L_m i_{dr}] \tag{8}$$

$$v_{dr} = -R_r i_{dr} + s\omega_s[(L_r + L_m) i_{qr} + L_m i_{qs}] \tag{9}$$

$$v_{qr} = -R_r i_{qr} - s\omega_s[(L_r + L_m) i_{dr} + L_m i_{ds}] \tag{10}$$

$$Q_s \geq -\frac{v_s^2}{\omega_s(L_s + L_m)} - \frac{L_m v_s}{L_s + L_m} \sqrt{i_r^{max^2} - \left[\frac{P_s(L_s + L_m)}{v_s L_m}\right]} \tag{11}$$

$$Q_s \leq -\frac{v_s^2}{\omega_s(L_s + L_m)} + \frac{L_m v_s}{L_s + L_m} \sqrt{i_r^{max^2} - \left[\frac{P_s(L_s + L_m)}{v_s L_m}\right]} \tag{12}$$

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Conference Publications

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2. R. K. Samal and M. Tripathy, "Wind resource assessment and energy analysis for wind energy projects," 2017 6th International Conference on Computer Applications In Electrical Engineering-Recent Advances (CERA), **IIT Roorkee**, 2017, pp. 128-133. doi: 10.1109/CERA.2017.8343314.
3. R. K. Samal and M. Tripathy, "Impact of Load and Wind Uncertainties on Capacity Factor of Thermal Generators" 2018 2nd International Conference on Power, Energy and Environment: Towards Smart Technology (ICEPE), **NIT Shillong**, June 1-2, 2018.

Thank You