Course no.: ENR 121
Course title: **Issues in Grid Integration of Power from Renewable Energy Sources**
Core or elective: Elective
Number of credits: 3
Number of lectures-tutorials-practicals: 14-14-14
Course coordinator:

Course outlines:
Grid integration is an important power system aspect. The various challenges and related issues must be addressed to the students for better understanding of the renewable energy sources and their applications. Keeping this in mind, the course has been developed to make students conversant with various devices / machines used for solar / wind power generation. Also, the integration related aspects will be discussed in detail. The course is oriented more towards analyzing the various simulation and lab experiments.

Evaluation procedure:
- Assignments/Lab: 20 %
- 2 Minor Test: 20 % each
- Major test: 40 %

Details of course content and allotted time

S. No.	Topic	Allotted time (hrs)		
		L	T	P
1	**Introduction:** Introduction to renewable energy grid integration, concept of mini/micro grids, and smart grids.	1		
2	**Synchronous Generator based sources:** Review of synchronous generators, Introduction to power system stability problems: rotor angle stability, voltage stability and voltage collapse, classification of stability. Modelling of synchronous machines: dq transformations, synchronous machine representation in stability studies.	2	2	
3	**Induction Generator based sources:** Introduction to induction machines: electrical characteristics, slip, speed-torque characteristics etc. Self excited induction generator, Constant speed Induction generators, Variable speed Induction generators, Doubly fed Induction generators.	2	2	
4	**Converter based sources:** Introduction to power electronic devices, AC/DC converters, PWM, THD. Permanent magnet synchronous generator, solar PV systems, fuel cell, aquaelectrolizer.	2	2	
5	**Grid Integration:** Issues in integration of synchronous generator based, induction generator based and converter based sources together. Network voltage management (discusses the issue of voltage levels). Power quality management (voltage dips, harmonics and flickers). Frequency management. Influence of WECS on system transient response.	3	6	

	System protection. Grid codes. Need of micro and smart grids.			
5	**Various Power system studies**: Various load forecasting techniques. Small signal stability, introduction to transient stability, voltage stability.	4	2	
6	**Simulation Lab:** In the simulation lab students will simulate various grid connected / offgrid systems on Matlab / DIgSILENT platform. These studies include: 1. Simulating a grid connected/off grid PV system and performing various power system studies. 2. Simulating a grid connected/off grid WECS and performing various power system studies. 3.Simulating a small grid consisting of various renewable energy sources and performing power system studies on it.			14
	Total	**14**	**14**	**14**

Suggested readings

Books:

1. Brendan Fox et. al.: **Wind Power Integration connection and system operational aspects**, IET Power and Energy Series 50 (2007).
2. Marco H. Balderas (ed.): **Renewable Energy Grid Integration**, (Nova Science Publishers, New York, 2009).
3. Nick Jenkin, Janaka Ekavayake: **Wind Energy Generation Modeling and Control** (Wiley and Sons).
4. AJ Wood and BF Wollenberg: **Power Generation, Operation and Control** (John Wiley & Sons, New York, 1996).

References:

1. Analysis of demand response and wind integration in Germany's electricity market, M. Klobasa, IET Renew. Power Gener., Vol. 4, No.1, pp. 55–63 55, 2010.
2. Impact of wind power on the power system imbalances in Finland, A. Helander1, H. Holttinen, J. Paatero, IET Renew. Power Gener., Vol. 4, No. 1, pp. 75–84, 2010.
3. Comparative analyses of seven technologies to facilitate the integration of fluctuating renewable energy sources, B.V. Mathiesen H. Lund, IET Renew. Power Gener., Vol. 3, NO. 2, pp. 190–204, 2009.
4. Advanced grid requirements for the integration of wind farms into the Spanish transmission system, Morales1, X. Robe1, M. Sala, P. Prats, C. Aguerri, E. Torres, IET Renew. Power Gener., Vol. 2, No. 1, pp. 47–59, 2008.
5. Impact of widespread photovoltaic generation on distribution systems, M. Thomson and D.G. Infield, IET Renew. Power Gener, Vol. 1, No.1, pp. 33–40, 2007.
6. Teri Mini Grid Project at Gual Pahari.

Journals and Magazines:

1. IEEE Transactions on Power Systems.

2. IET Renewable Power Generation.
3. IET GTD (Generation, Transmission and Distribution).

Reviewers

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