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All Island TSO Facilitation of Renewables Studies WP1 – Technical Studies

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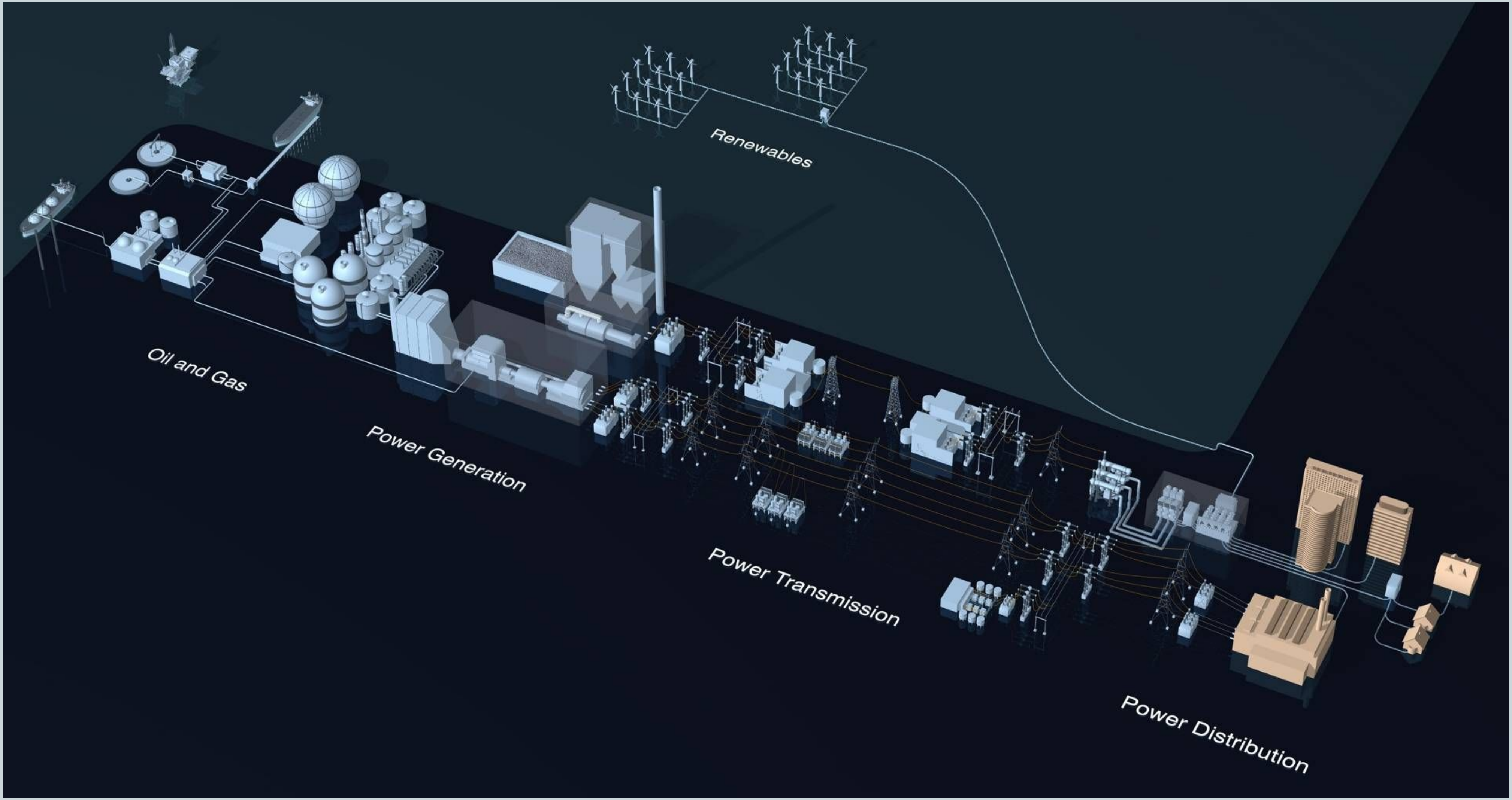
9th November 2009
Dublin

EIRGRID

SONI
Systems Operator for Northern Ireland

Siemens Energy Sector
primary energy to power distribution



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Overview

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§ **Introduction to the Project & Technical Studies**

§ **Work to Date**
- Modelling
- Data processing
- Study pre-processing & automation

§ **Example/preliminary results**

§ **Next steps**

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Why ?

Basic requirement from EIRGRID/SONI is 40% of generation from renewables by 2020, comprising:

- **109MW of Biomass**
- **250MW of Tidal**
- **84MW of Wave**
- **7550MW of Wind**

Introduction

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Project divided into 3 Work Packages:

- **Work Package 1: Technical Studies**
  - **series of technical studies intended to inform future operation of the system by facilitating increased understanding of the behaviour of the power system with large amounts of wind generation**
- **Work Package 2: System Frequency Studies**
- **Work Package 3: Analysis of WP1 and WP2**

Work Package 1 Tasks

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Task 1.1 : Dynamic, Transient and Small Signal Stability

- Assess dynamic, transient and small signal stability issues with increased levels of renewable penetration

Task 1.2 : Fault Levels and Protection Operation and Philosophy

- Determine the impact of faults levels due to increased wind power penetration and the consequent reduced number of conventional synchronous machines connected

Task 1.3 : Congestion Management

- Determine the impact on the transmission network of increased levels of wind generation and geographic variances in wind production

Work Package 1 Tasks

Task 1.4 : Reactive Power and Voltage Control

Identify reactive power capability and utilisation requirements along with voltage control methodologies in order to ensure voltage stability with significant levels of WTG connected at distribution levels

Task 1.5 : System Flexibility Requirements

Determine the needs of the power system with large amounts of wind power and increased demand side participation

Aims of Studies

T1.1 Impact of large penetration of wind generation on power system stability

T1.2 Adequacy of existing and future equipment based on calculated short circuit currents

T1.3 Methods on the mitigation for transmission system bottlenecks for various wind generation patterns

T1.4 Updated voltage control schemes and recommendations for compensation devices

T1.5 Additional requirements for power/frequency control/ reserve caused by the stochastic nature of wind and variability of load

Project Milestones

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§ Methodology Report

- describes in detail project approach and methodology
- contains a brief introduction/background to the project, review of scope of work and associated objectives, description of the data required, study/analysis methodologies & scenarios/ sensitivity levels proposed.

§ Interim Report

- describes work undertaken to date

§ Final Report

Work to Date

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- Develop Load Flow cases of EIRGRID+SONI for 2020 including planned wind generation
- Develop Dynamic Models for the corresponding Load Flow cases
- Gather sequence data for balanced and unbalanced fault calculations
- Gather data for contingency analysis
- Gather statistical data for measured and forecast wind generation as well as load demand

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Task 1.1 – Load Flow

Load Flow cases generated by varying:

- **Load Level**
  - Winter Max, Winter Min, Summer Max, Summer Min
- **Wind Generation**
  - 25%, 50%, 75% and 100% of installed wind power
- **Wind Farm Connection Ratio**
  - 35% Tran / 65% Dist & 20% Tran / 80% Dist
- **Load Modelling Approach**
  - ZIP & ZIP + Induction Motors
- **Power Exchange**
  - 1350MW imp, 500MW imp, No Exchange, 500MW exp, 1350MW exp
- **Technology Split**
  - 85% DFIG / 15% Full Converter & 50% DFIG / 50% Full Converter

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Task 1.1 - Dynamics

Dynamic model generation using PSS/E Standard Dynamic Library models:

- **Double Fed Induction Generator [DFIG] (in study a.k.a. Type C)**
  - Based on Vestas V90, 3MW Turbine – Typical Parameters
    - Generator model – W3G2U
    - Electrical control model – WT3E1
    - Mechanical system model – WT3T1
    - Pitch control model – WT3P1
- **Fully Rated Converter Synchronous Generator (in study a.k.a. Type D)**
  - Based on Enercon E70, 2.3 MW Turbine – Actual Parameters
    - Generator + converter model – W4G1U
    - Electrical control model – W4E1U

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Sensitivity Analysis Volume

Each task requires sensitivity analysis by building cases with variation of certain parameters. The number of sensitivity base cases generated for each task is:

- **Task 1.1 – 99 sensitivity cases**
- **Task 1.2 – 39 sensitivity cases**
- **Task 1.3 – 26 sensitivity cases**
- **Task 1.4 – 39 sensitivity cases**
- **Task 1.5 – 39 sensitivity cases**

Total – 242 models

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Development of Repeatable Process

Automation files developed for:

- Connection of existing and new wind farms into base case load flow models
- Incorporation of sequence data into load flow models
- Creation and addition of dynamic data files
- Creation of contingency analysis files for task 1.3

Power Balance Scenario 1

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Winter Maximum Demand

P Load	7550MW
P Losses	378MW
P Pumped Storage Pumping	290MW
P Other Renewable Generation	-443MW
P Total Consumption	7775MW

Total Pgen [MW]		HVDC exchange of power (- for import, + for export)				
Wind generation		1350	500	0	-500	-1350
%	MW	MW	MW	MW	MW	MW
100	7550	1574.5	724.5	224.5	-275.5	-1125.5
75	5662.5	3462	2612	2112	1612	762
50	3775	5349.5	4499.5	3999.5	3499.5	2649.5
25	1887.5	7237	6387	5887	5387	4537
0	0	9124.5	8274.5	7774.5	7274.5	6424.5

Red: Non feasible scenario

Yellow: Possibly feasible scenario

Power Balance Scenario 2

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Winter Minimum Demand

P Load	3520MW
P Losses	176MW
P Pumped Storage Pumping	290MW
P Other Renewable Generation	-443MW
P Total Consumption	3543MW

Total Pgen [MW]		HVDC exchange of power (- for import, + for export)				
Wind generation		1350	500	0	-500	-1350
%	MW	MW	MW	MW	MW	MW
100	7550	-2657	-3507	-4007	-4507	-5357
75	5662.5	-769.5	-1619.5	-2119.5	-2619.5	-3469.5
50	3775	1118	268	-232	-732	-1582
25	1887.5	3005.5	2155.5	1655.5	1155.5	305.5
0	0	4893	4043	3543	3043	2193

Red: Non feasible scenario

Yellow: Possibly feasible scenario

Power Balance Scenario 3

Summer Maximum Demand

P Load	5938MW
P Losses	297MW
P Pumped Storage Pumping	290MW
P Other Renewable Generation	-443MW
P Total Consumption	6082MW

Total Pgen [MW]		HVDC exchange of power (- for import, + for export)				
Wind generation		1350	500	0	-500	-1350
%	MW	MW	MW	MW	MW	MW
100	7550	-118.1	-968.1	-1468.1	-1968.1	-2818.1
75	5662.5	1769.4	919.4	419.4	-80.6	-930.6
50	3775	3656.9	2806.9	2306.9	1806.9	956.9
25	1887.5	5544.4	4694.4	4194.4	3694.4	2844.4
0	0	7431.9	6581.9	6081.9	5581.9	4731.9

Non feasible scenario (red)

Possibly feasible scenario (yellow)

Power Balance Scenario 4

Summer Minimum Demand

P Load	2535MW
P Losses	127MW
P Pumped Storage Pumping	290MW
P Other Renewable Generation	-443MW
P Total Consumption	2509MW

Total Pgen [MW]		HVDC exchange of power (- for import, + for export)				
Wind generation		1350	500	0	-500	-1350
%	MW	MW	MW	MW	MW	MW
100	7550	-3691.25	-4541.25	-5041.25	-5541.25	-6391.25
75	5662.5	-1803.75	-2653.75	-3153.75	-3653.75	-4503.75
50	3775	83.75	-766.25	-1266.25	-1766.25	-2616.25
25	1887.5	1971.25	1121.25	621.25	121.25	-728.75
0	0	3858.75	3008.75	2508.75	2008.75	1158.75

Non feasible scenario (red)
Possibly feasible scenario (yellow)

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Load Flow Issues

- **‘Inadequate’ connection of future wind farms to transmission and distribution networks**
  - Large wind farms connected to weak distribution network
  - Wind farms connected to generator bus bars
- **Voltage control issues**
  - Investigation into coordinated voltage control and subsequent optimisation method(s)
- **Ranking order of generators**
  - For some sensitivity cases excessive conventional generation displaced (decrease of reactive power reserve in load flow, substantially lower power/frequency control reserve)

Dynamic Modelling of Wind Generation

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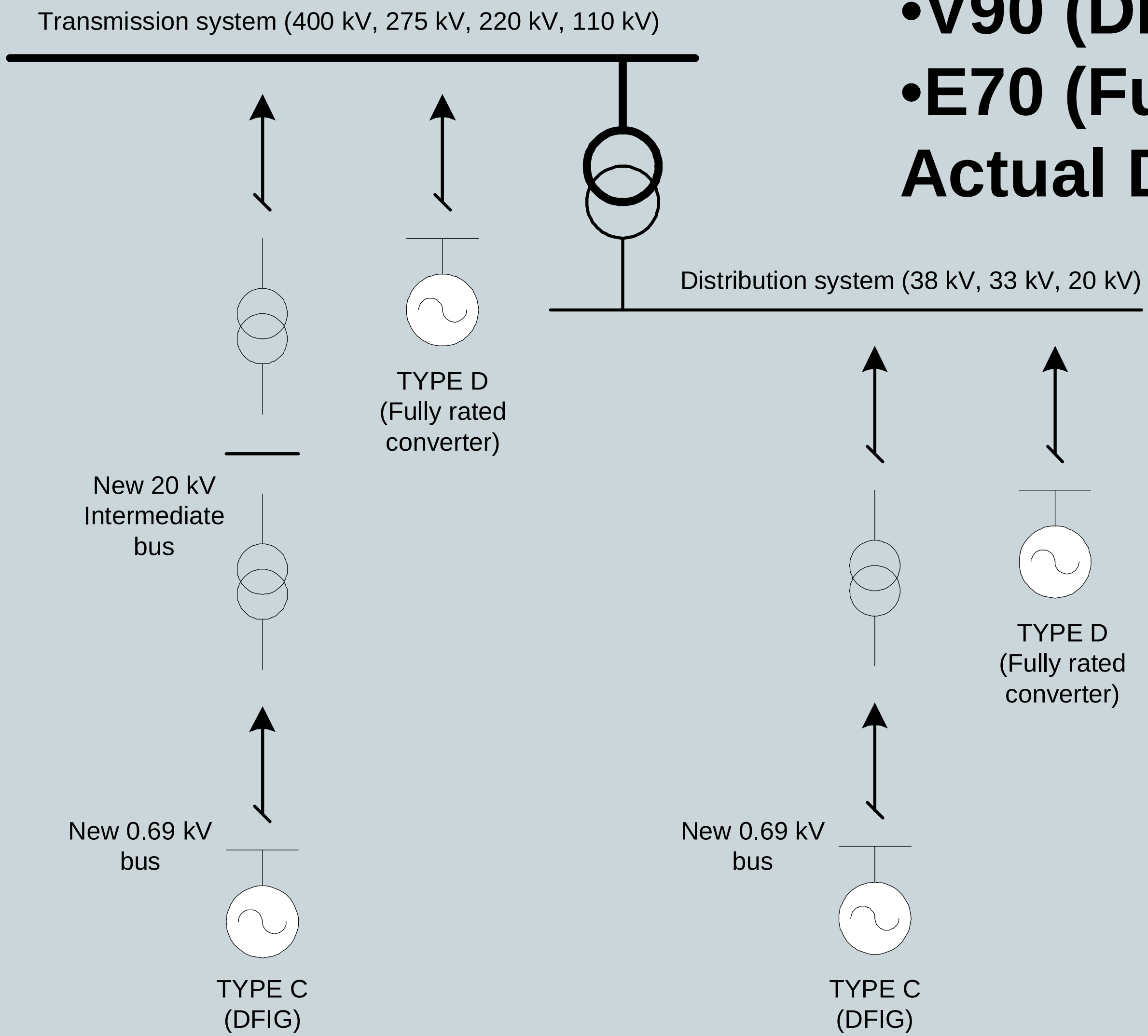

- V90 (DFIG) Standard Data
- E70 (Fully Rated Converter) Actual Data

Dynamic Modelling of HVDC

HVDC Line Name	**HVDC Line Type**	**Dynamic Model of HVDC Line**
Moyle 2x200kV, 500MW Ballylumford – Auchencrosh	Current Source Converter, Bipolar	User Defined model CSIMEN
East – West I 2x200kV, 500MW Woodland – Deeside	Voltage Source Converter, Bipolar	Standard PSSE model VSCDCT
East – West II 2x150kV, 350MW Arklow – Pentir	Voltage Source Converter, Bipolar	Standard PSSE model VSCDCT

Task 1.2
Modelling Prerequisites

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- **Generator sub transient reactances (source)**
  - Unsaturated values used by SONI
  - Saturated values used by Eirgrid
- **Short Circuit infeed from HVDC not taken into account**
- **New transformers connected to new wind turbines will be modelled as YNd1 (d ≡ LV)**

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Task 1.3

- Analysis will be based on results from T1.1 and 1.5
- The models resultant of T1.1 - Load Flow will be used to determine suitable outage list for the contingency analysis
- T1.5 will determine dispersion and participation factors for wind generators
- Total Transfer Capacity (TTC) will be calculated using PSS/E PV analysis tool

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Task 1.4

- Results from T1.1 are utilised to indicate where potential congestion problems might be found
- QV analysis will be used, if necessary, to identify mitigation strategies

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Task 1.5

Statistical Analysis:

- Future Load forecast error will be extrapolated using current trends in existing load forecast errors

- Future Wind generation forecast error will be calculated using an extrapolation function involving current wind forecast error against average wind power

- Probabilistic forecast of conventional generation outages by selection between the units with largest installed power and the unit with the largest outage rate

- Statistical analysis results will be utilised to determine the required power reserve for the system

Interim Results

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[All-Island-SiemensPTI-WP1-091109-part3.ppt]

[All-Island-SiemensPTI-WP1-091109-part4.ppt]