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SKM

Independent Market Operator

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Office of Energy

western power

Impacts of Intermittent Generation

SCOPING DOCUMENT TO ASSESS THE IMPACTS OF INTERMITTENT GENERATION

- Scoping Document
- Final
- 3 May 2009

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1. Introduction

Sinclair Knight Merz (SKM) has been commissioned by the Independent Market Operator (IMO) to develop a scope of works (a Work Program) to review the impacts and challenges associated with the increasing levels of intermittent generation penetration into the South West Interconnected System (SWIS).

The Work Program has been developed in consultation with the IMO, the Office of Energy (OoE) and Western Power System Management (System Management) and is intended to address the differing concerns and requirements of each organisation together with that of energy generators and consumers. The challenges facing each organisation are primarily concerned with understanding how the renewable energy targets will alter investment in both generation and network assets and how the resulting higher level of intermittent generation will impact the operation of the market and the power system.

As each organisation's charter is different, appropriately addressing the concerns within the Work Program presents a challenge within itself. Market based initiatives together with and in place of mandated technical standards will need to be given apposite consideration in terms of resolving the technical challenges associated with the connection of intermittent generators to the network. The timeframe for the development of appropriate strategies, policies and rules for the integration of intermittent generation into the SWIS will need to be considered from a short term and long term perspective so as to evolve and mature ahead of the intermittent generation market. In doing so, the SWIS Wholesale Energy Market (WEM) and Technical Rules will not inhibit the national objectives of achieving renewable energy usage.

It is expected that the resultant output from the Work Program will find satisfactory solutions to the challenges and that the primary driver of achieving the market objectives, including the safe and reliable production and supply of electricity, will be met.

Within the context of this document, renewable energy sources such as wind, solar and tidal are considered to be variable or intermittent due to the uncontrollable nature of the primary fuel source. Output from other renewable sources such as biomass, geothermal and to some degree solar thermal is more controllable and less intermittent in nature. The primary focus of the Work Program is to assess the implications of increasing levels of intermittent generation; however, appropriate investigation into renewable generation that is more controllable should also be considered in the Work Program. It should also be noted that variability and intermittency should not be confused with unreliability or unpredictability as previous studies have shown that the availability and reliability of renewable generators such as wind turbines is equivalent to conventional thermal plant.

In order to facilitate the increasing penetration of intermittent generation on the SWIS, there are a number of documents that will be under examination throughout the Work Program. Principally, these are:

1. Electricity Industry (Wholesale Electricity Market) Regulations 2004;
2. Power System Operating Procedure: Ancillary Services;
3. Technical Rules; and
4. Market Rules

Whilst the rules and requirements listed in these documents will have a significant bearing on the integration of intermittent generation, there may be other documents that require attention. It is envisaged that the identification, review and investigation of these documents will be undertaken during the course of the Work Program.

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2. Challenges faced with increasing levels of intermittent generation

There is a significant amount of literature available both nationally and internationally that discusses the principle challenges associated with increasing levels of intermittent generation penetration and the impacts this has on the relevant electricity jurisdictions. Indeed, investigations into intermittent generation penetration on the SWIS have already been undertaken previously and have concluded that energy penetration levels of up to and higher than 20% may be possible should all the concerns be adequately addressed[1]. Due to the significant momentum that now exists from State and Federal Governments, changes to the sources and usage of primary energy and electricity could appear sooner than expected. This has increased the urgency on the IMO, System Management and the OoE to deliver appropriate solutions that will preserve the network and market objectives and operation during the rapid deployment of renewable energy generators.

The Government is using two particular mechanisms to promote the introduction of low greenhouse emission and renewable energy, namely the Carbon Pollution Reduction Scheme (CPRS) and the Mandatory Renewable Energy Target (MRET). Both schemes act to incentivise renewable generation development by effectively normalising the higher cost typical of renewable generation with conventional plant. Again, there is a significant amount of literature available both nationally and internationally that addresses the implementation of the schemes and the flow on effects this is likely to have on the future generation mix. The common underlying theme is that energy from renewable sources will increase and electricity networks and markets will need to adapt to the technical challenges introduced by these new technologies. Providing timely solutions to the technical concerns and thorough engagement between all stakeholders in the early stages will be critical to avoiding inefficient investment in generation.

Wind generation is the first renewable energy resource other than hydro that has achieved substantial grid penetrations within electricity networks worldwide and the SWIS is no exception. It is also considered likely that wind will remain a major renewable generation source for at least the next decade or two. As a consequence, managing the connection of wind to the grid is the frontrunner to addressing the issues associated with intermittent generation.

The issues and challenges associated with the integration of intermittent generation that face all electricity networks are similar. Principally, these can be categorised into:

1. technical;
2. commercial; and

[1] South West Interconnected System (SWIS), Maximising the Penetration of Intermittent Generation in the SWIS. Econnect Project No: 1465

3. Regulatory.

The challenge for market operators, regulators and system operators is to design enhancements to the rules and market that achieve the Market objectives while meeting the targets set by the Government. The similarities and subtleties that distinguish the SWIS from other markets and the principle challenges faced by the IMO, System Management and the Office of Energy in the context of integration of intermittent generation in the SWIS are:

1. Ability of the system to respond to the increased rate of change of load. i.e. a Frequency Control Ancillary Service (FCAS) Standard;

2. Requirement to increase the quantum of FCAS and balancing quantities that must be carried by the network;

3. Technical Rules Requirements;

4. Generation capacity and geographic and energy source diversity. Addressing how intermittent generators may contribute to the Reserve Capacity Mechanism, how the market encourages geographic diversity for Network requirements and also how to facilitate energy source diversity.

The drivers and challenges associated with the increasing levels of intermittent generation penetration onto the SWIS network need to be comprehensively understood and proactively managed. The short and long term restructuring of the market and technical requirements will need to provide a level playing field for new and existing generators that does not favour any particular technology but also rewards appropriately the merits of the different technologies. The market and technical requirements should consider an appropriate allocation of risks, costs and benefits to participants with the intention of ensuring market price based decisions.

The challenges and areas for consideration are discussed in detail in the following sections.

2.1. Type of Frequency Control Ancillary Services

Due to the variability of an intermittent generator's fuel source, frequency stability is a principle challenge as penetration levels increase. With low levels of penetration, previous studies on the SWIS and international networks have shown that output variability can be managed satisfactorily under the existing requirements established for conventional generators. Network frequency stability with respect to output variability is typically managed by Frequency Control Ancillary Services (in the WEM, the ancillary services that facilitate this are Load Following, Spinning Reserve and Load Rejection).

The provision of FCAS from both intermittent and conventional generators will need to be considered. The type of services required in the short and long term along with how these services should be procured is the principle focus of the investigation. Exploration of concepts such as considering the curtailment of intermittent generators as an FCAS (whereby intermittent generators reduce output at times of minimum system demand when conventional plant cannot reduce its output) should be undertaken.

From a market perspective, the allocation of costs and benefits to participants will need to be reflective of the costs and benefits each provide to the industry. As the penetration of intermittent generation increases, the requirement to accurately predict output becomes critical. In a similar way to that described above, this is both a technical and market challenge. From a technical perspective, correctly predicting wind output can assist the system operator's ability to maintain system security as they will be able to dispatch generation with a reasonable degree of foresight. This in turn will help reduce the requirement for ancillary services which should result in lower costs for these services in the market. Determining the type of services required to adequately respond to the prevailing generation mix is an important aspect of the Work Program.

2.2. Quantum of Frequency Control Ancillary Service

Changes to the quantum of FCAS required as intermittent generation penetration increases will need to be addressed. In the WEM, System Management balances the system by purchasing services from generators or adjustable loads (FCAS). This balancing requirement leads to additional costs that should be appropriately passed on to consumers. Currently in the SWIS, energy balancing is charged at the Marginal Cost Administered Price (MCAP), the Short Term Energy Market (STEM) settling price and is provided from one provider (Verve). Therefore in the present market arrangement, increasing the quantum required for balancing energy would not necessarily increase the cost per unit of energy to the market. Clearly providing energy balancing services results in an increase to the underlying cost, but these may not be adequately recovered by the provider and passed on to the market.

Due to the variable nature of intermittent generators output, a greater degree of balancing will be required as penetration levels rise. This will in turn lead to higher costs. Global studies have estimated that these costs are less than $13/MWh of intermittent output[2]. The underlying costs of providing the services required and the ability of the market to appropriately pass these costs through is one of the principle focuses of the investigation.

[2] The Costs and Impacts of Intermittency: An assessment of the evidence on the costs and impacts of intermittent generation on the British electricity network, UK Energy Research Centre, March 2006

A system margin (spinning reserve and load rejection in the WEM) is needed to cope with the unavailability of installed generation. Similarly to energy balancing (load following in the WEM), increased penetration of intermittent generation increases the size of the system margin (spinning reserve) required to maintain a given level of reliability[3]. The additional capacity to maintain reliability entails costs over and above the direct cost of generating from intermittent sources.

The quantum of FCAS due to output variability of intermittent generators is a challenge that needs to be addressed as levels of intermittent generation penetration increase. The network diversity and characterisation of intermittent resources will need to be considered and will play an important role in determining the requirements for FCAS. Correctly determining the requirements is an important consideration from both a technical and market perspective as significant increases in intermittent generation penetration will naturally lead to greater amounts of energy being dispatched for balancing and should be reflected in the cost of electricity if the market is configured appropriately.

2.3. Technical Rules Requirements

Network stability with respect to fault ride through characteristics of intermittent generators will need to be considered. This is a complex issue to resolve from a technical perspective and requires significant modelling and validation through site testing. Additionally, determining the characteristics on a dynamic network where new proponents enter alongside existing ones is challenging. The challenges are further exacerbated by an increasing number of Market Participants and it is considered infeasible to continually revise the requirements as the network configuration changes.

Mandating stringent fault ride through technical requirements on intermittent generators would on the surface appear to favour incumbent technologies and does not take into account the network diversity of the intermittent generators. It is also likely to have a flow on effect to the cost and hence viability of intermittent generators and could potentially lead to legal issues associated with the provision of equal access to the grid for all generators. Market based alternatives to fault ride through such as the payment by an intermittent generator of a spinning reserve charge to cover the risk associated with disconnecting during a fault and / or locational payments for the provision of spinning reserve are worth considering.

2.4. Capacity and Diversity

The existing Reserve Capacity Mechanism (RCM) in the SWIS recognises the contribution intermittent generators make towards system security and capacity, however, as penetration levels rise, it will be necessary to improve the understanding of the contribution that intermittent

[3] The Costs and Impacts of Intermittency: An assessment of the evidence on the costs and impacts of intermittent generation on the British electricity network, UK Energy Research Centre, March 2006

generators make to system reliability, and adjust methods for remunerating the capacity they provide.

Charging proponents a cost reflective amount for new connections would provide a mechanism to incentivise generation at locations where network reinforcements can be avoided and this could reduce network costs. Geographic diversity of generation and the network reinforcements required to support high levels of intermittent generation together with consideration of cost sharing and differential use of system charges will be necessary. The SWIS is characterised by small power flows over a large geographical area. An objective of the Western Australia Electricity Code is to ensure a balance between the interests of new and existing market participants is achieved. For network augmentations that satisfy the requirements, the SWIS Network Operator is required to undertake the investment and recovers the cost through charging a use of system tariff to all users. With increasing levels of intermittent generation, it may be necessary at some stage in the future to carry out a system wide upgrade. There is currently a requirement in the SWIS for the Network Operator to reduce the use of system charge for a distributed generator where it leads to a cost reduction in costs for the Network. Implementing this on the SWIS for all generators may provide incentives to investment and economic efficiencies for the market as a whole.

3. Comparisons with International Experience

3.1. The SWIS

Western Australia has low emission, renewable energy resources which represent an opportunity, if the risks posed by the integration of new technologies into the market are appropriately managed, to develop sustainable generation alternatives to traditional fossil fuel generation.

The SWIS is characterised by a relatively small sized electricity network spread over a large geographical area with a homogenous generation mix (predominately coal and gas) and a capacity and ancillary service market dominated by one main generation entity (Verve). One of the consequences of these characteristics is that the integration of intermittent generation is a complex and challenging issue and will require a considered and possibly staged approach.

While on one hand the integration of renewable energy generators could contribute positively to the security of supply as it diversifies the generation mix and thereby reduces the risks associated with a reliance on one or two fuel sources, it does raise the risk profile of grid stability as a consequence of the variability of renewable generation output. In addition, there is a financial premium to be paid for Wind Power Generators[4]. These increased costs are associated with providing adequate levels of system balancing and system capacity (i.e. margin or reserve respectively).

Given the relatively small size and island nature of the SWIS, material changes to the configuration of the existing generation mix and in particular the operating characteristics of individual units may have a significant impact on the ability of the System Management to maintain system stability. Similarly, by displacing the output from thermal plant and substituting this with output from intermittent generators, a material impact on the electricity market may eventuate as a result of increasing the requirements for the provision of frequency keeping services (spinning reserve, load following and load rejection).

As mentioned above, Verve presently plays a significant role in supplying the system with energy and providing system security through ancillary services. The large scale integration of intermittent generation into the SWIS is likely to result in a material impact on Verve in terms of a reduction in saleable output and a requirement to supply the necessary ancillary services to ensure system security. It is noted that the non renewable capacity of Verve has been capped by legislation allowing them to grow capacity in renewable sources only. In some cases this entity is bearing the cost of maintaining system security with limited mechanisms to pass these costs back to the market. In the event that the Technical and Market Rules remain unchanged, there may be a

[4] Impact of Wind Power Generation In Ireland on the Operation of Conventional Plant and the Economic Implications, ESB National Grid, February 2004

potential upside for new proponents of intermittent generators while existing generators may find themselves in an untenable position. Equally, it may also be the case that new proponents find they are not able to gain access to the network under the existing network connection rules despite the market encouraging their entry. The technical and market framework will need to work in conjunction as the generation mix changes in order to preserve the integrity of market objectives.

In terms of geography, the integration of intermittent generation into the SWIS also presents significant challenges. The network diversity, access and usage charges and uncertainty surrounding the characterisation of intermittent resources could inhibit the introduction of viable generation.

A review of international electricity markets found that there is no market that entirely duplicates the unique characteristics of the SWIS. With respect to comparisons to other markets, a report prepared by the UK Energy Research Centre (UKERC)[5], noted that "*The greatest care must be taken in trying to make such comparisons. The impacts and costs of intermittent generation can be assessed only in the context of the particular type of system in which they are embedded.*" This is supported by a paper[6] by the International Energy Agency (IEA) "*the results on the cost of integration differ and comparisons are difficult to make due to different methodology, data and tools used, as well as terminology and metrics in representing the results*".

The UKERC report identified the following dependencies in assessing the costs and impacts of intermittent generation which result in it being challenging to make useful comparisons between different networks:

(i) The quality of the environmental resource on which renewable generation depends, for example the strength of the wind and the degree to which it fluctuates;

(ii) The robustness of the electricity grid and the capacity to transfer power from generators to consumers;

(iii) Regulatory and operating practices, in particular how far ahead the use of system balancing reserve is planned (known as 'gate closure'). The closer to real time reserves are committed, the more reliable the forecasts of intermittent generation will be, which can reduce the need for more expensive fast-acting reserve.

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5 The Costs and Impacts of Intermittency: An assessment of the evidence on the costs and impacts of intermittent generation on the British electricity network, UK Energy Research Centre, March 2006
6 Hannele Holttinen, et al. (September 2006). “"Design and Operation of Power Systems with Large Amounts of Wind Power", IEA Wind Summary Paper", Global Wind Power Conference September 2006

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(iv) Accuracy of forecasting of intermittent output. Better forecasting can improve the efficiency with which intermittency is managed, both by the system operator after gate closure and by markets over longer timescales. Weather patterns in some regions are more predictable than in others; and

(v) The extent to which intermittent generators are geographically dispersed or are located in a particular area. If wind generators are located close together their output will tend to fluctuate up and down at the same time, increasing variability of the total output and increasing the costs of both system balancing and maintaining reliability.

While it is necessary to study each electricity market and network within the context of the system itself, this is not to say that useful insight cannot be gained from considering how the generic issues associated with the integration of wind generation are treated in other jurisdictions. The UKERC report mentions that "*Some conditions in Britain (quality of wind resource, robustness of the grid, relatively late gate closure) will tend to mitigate the impacts of intermittency and keep associated costs relatively low. Others (notably the relative lack of interconnection and the relatively small geographical area over which resources are dispersed) will tend to increase the costs of managing the system relative to other regions. Comparisons between Britain and other countries must be treated with the greatest of caution.*" In some ways the SWIS shares similarities with the Britain system (quality of wind resource, robustness of the grid, lack of interconnection and relatively small dispersion). That said, the United Kingdom installed system capacity is almost double that of the installed capacity of Australia (79.7 GW to 49.5 GW).

A review of electricity markets identified that Ireland (which is similar to Britain) does have strong correlations to the SWIS with respect to the installed capacity and the present and forecast penetration of wind generation. The installed capacity in Ireland is 8.1 GW and the penetration of wind has increased from around 2% in 2002 to around 15% in 2008[7] (expressed as a percentage of installed capacity, not energy). A report by ESB National Grid[8], noted that in 2004, there was 210MW of Wind Powered Generation (WPG) connected to the Ireland network, with a further 598MW with signed connection offers and 900MW of connection applications. This is similar to the present situation found in the SWIS where there is a relatively small amount of WPG connected to the system and the prospect of significant amounts of WPG connecting in the near future. It is

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[7] International Energy Annual 2006, Energy Information Administration
Global Wind Energy Council (GWEC) statistics
European Wind Energy Association (EWEA) statistics
Global installed wind power capacity (MW) Global Wind Energy Council

[8] Impact of Wind Power Generation In Ireland on the Operation of Conventional Plant and the Economic Implications, ESB National Grid, February 2004

reasonable to consider that the Ireland network and market are around 5 years more mature than the development of the SWIS and it is therefore worth investigating further.

While other electricity networks were considered, the characteristics are not particularly well suited for comparison to the SWIS. Generally speaking, the networks are either significantly larger or smaller than the SWIS, have significant interconnection to other networks and / or the present and forecast penetration of WPG does not match that of the SWIS. A 2006 paper[9] by the International Energy Agency (IEA) reviewed wind generation integration studies undertaken on systems in Denmark, Finland, Germany, Ireland, Netherlands, Norway, Portugal, Sweden, UK and the USA. The review of these networks found that there is a considerable disparity in reserve requirements and balancing costs for different countries and regions. In many cases, this is due to different time scales used (reserve requirements and variability from day-ahead to hourly), different consideration of transmission interconnections and alternative methods for incorporating new reserve and operating costs.

3.2. The Ireland Electricity Market

As mentioned above, the SWIS market has a number of strong correlations with the electricity market of Ireland. In particular these are[10]:

a) By international standards the SWIS is relatively small with peak demand of around 3,800 MW and installed capacity of around 5,000 MW. The market in Ireland has a peak demand of around 4,900 MW and installed capacity of around 8,100 MW;

b) Compared to most markets the two systems are essentially 'island' operations. While there is a 400MW interconnection with GB (installed capacity of 79,700 MW) the relative size of the interconnection is only considered moderate.

c) The electricity market in Ireland has recently become harmonised with that of Northern Ireland and a single competitive Pool has been introduced. As the move begins away from a largely vertically integrated structure, the similarities with the SWIS are strong;

d) The dominant player in each reformed market remains the state owned incumbent – although competition is increasing;

e) In a similar way that Ireland's onshore wind resource is amongst the best in Europe, the wind resource in the SWIS is amongst the best in Australia. In each market the

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[9] Hannele Holttinen, et al. (September 2006). "'Design and Operation of Power Systems with Large Amounts of Wind Power", IEA Wind Summary Paper", Global Wind Power Conference September 2006

[10] The strong correlation between the two systems was recognised in an Econnect report: South West Interconnected System (SWIS), Maximising the Penetration of Intermittent Generation in the SWIS. Econnect Project No: 1465

penetration of wind is set to increase substantially due to favourable wind resources and programs to drive investment in low emission and renewable energy technologies;

f) The wind turbines connected and proposed for connection in Ireland and the SWIS are more modern than in other countries with high penetrations of wind such as Denmark (~24%), Spain and Germany (~14%). The older turbines in these jurisdictions tend to be simple induction generators that provide little or no technical or contractual way of control by the system operator.

Given the physical similarities between the two markets and that Ireland embarked on its process of reform sooner and is seeing this process intensified with the creation of a single electricity market between Ireland and Northern Ireland (a UK jurisdiction), the experience of the Irish market provides some useful insights into some of the issues challenging the SWIS.

3.2.1. Background

The first wind farm in Ireland was brought on line in 1992 with a capacity of 6.45MW and following a slow growth throughout the 1990's and early 2000's there has been rapid acceleration since 2003 where levels of capacity have increased from around 166MW to over 520MW installed and 751MW of signed offers to connect in 2006. This represents over 8% of installed capacity currently and potentially up to 15% should all the proponents with offers connect.

Due to the substantial acceleration in connection applications in 2003 and uncertainty surrounding the connection and operation issues, the Transmission System Operator (TSO) proposed a moratorium on issuing new connection agreements in order to allow time to address the technical challenges associated with accommodating wind power penetration levels beyond the amount already committed. The concerns related to maintaining the stability, security and reliability of the power system. Of particular relevance, the TSO identified the absence of a Grid Code specific to wind generators, dynamic models of wind turbines to facilitate the assessment of wind power on dynamic performance of the network and reliable wind power forecasting as suitable grounds for justifying the moratorium.

The Grid Code was revised to incorporate a specific section dealing with the concerns associated with the connection of wind generators with regard to fault ride through capability, frequency requirements, voltage requirements and signals, communications and controls including meteorological data, availability data, MW displacement data and frequency response settings.

Due to the potential for constraints to have a significant impact on the viability of wind farm projects, the TSO also assessed the likely anticipated level of constraints in order to provide initial indications to the wind generators and financiers. This subsequently led to further forecasting activities and initiatives and the development and use of a multi-scheme ensemble wind energy prediction system.

Given the requirement for accurate representative models as a pre-condition for the acceptance of a grid connection application, wind turbine manufacturers have produced and presented the models to the TSO for testing and validation. In late 2006, dynamic modelling was no longer considered a stumbling block; however, the successful incorporation of all models into a full system model remains unresolved and as such, uncertainties still exist regarding the impacts of wind generated electricity and the ability of generators to comply with the grid code.

The following sections address the Grid Code and market issues of the Ireland system.

3.2.2. Grid Code Compliance

In a relatively small power system it is very important for the efficient and economic operation of the power system to ensure that the generators maintain the performance required in the Grid Code as appropriate generator performance helps the system operator minimise costs. Given that the only penalty measure for non-compliance with the Grid Code in Ireland is the extreme licence revocation, it was argued that there were insufficient incentives for generators to maintain Grid Code performance.

The underlying principle for the development of additional performance incentives is that there should be no increase in cost to the electricity consumer. A generator performance incentive scheme of withholding ancillary services payments, coupled with a penalty mechanism which will take the form of an amount charged to the unit which is a multiple of the rate paid for performance is to be introduced.

As mentioned above, revisions were made to the grid code following the moratorium to better deal with the connection of wind farms. Specific revisions included:

- Fault ride through capability. This required wind farms to remain connected to the system for voltage dips down to 15% nominal voltage for 625ms on all phases and to provide active power and maximise reactive current;
- Frequency requirements. Acceptable limits of generator performance across a range of system frequencies were mandated including the requirement to remain connected for frequencies between 47.5Hz and 52.0Hz for 60 minutes. Additionally, frequency control including the capability of operating each wind farm at a reduced level, following specific power frequency requirements and controlling ramp rates of active power;
- Voltage requirements. This required wind farms to remain connected at maximum power output for step changes in transmission voltage of up to 10% and to have a continuously

active voltage regulation system that modulates the reactive power output to change the voltage set point at the connection; and

- Communications requirements. This required wind farms to provide signals and controls including meteorological data, availability data, MW displacement data and frequency response system settings. An important inclusion was the ability for wind farms to receive signals from the TSO and act accordingly.

From the TSO's perspective, this adequately dealt with the Grid Code issues associated with the connection of new wind farms to the all island Ireland grid.

The regulator directed the TSO to end the moratorium following approval of the revised grid code; however, this included a condition that all future offers of connection would be made on the basis that the output of the wind farm may be constrained for system reasons.

3.2.3. Proposed treatment of Ancillary Services on the island of Ireland

In November 2004 a Development Framework for an All Island Energy Market was published, setting out the dates by which a Single Electricity Market (SEM) across the island of Ireland was to be achieved. The SEM high-level design was completed in June 2005 and the Regulatory Authorities set to work on the implementation of a suite of arrangements necessary for SEM Go Live by 1 November 2007. On 1 November 2007 the SEM came into effect with the trading and settlement of wholesale electricity in Ireland and Northern Ireland on an all island basis.

The SEM consists of a gross mandatory pool into which all electricity generated or imported onto the island of Ireland must be sold, and from which all wholesale electricity must be purchased. The key design features of the SEM are the pool arrangements where all generators receive and all supplier units pay the same single System Marginal Price (SMP) and a system of collection and distribution of payments for capacity based on fixed amounts is determined annually. The SEM also operates a Capacity Payment Mechanism similar to the RCM in the SWIS, this incorporates a variable and fixed payment mechanism for generation capacity.

At the present time, the structure, treatment and arrangements for the provision of ancillary services differ between Northern Ireland and Ireland. As part of a process of moving towards harmonising the treatment of ancillary services a number of key issues that are highly pertinent to the situation in the SWIS, in particular, these are:

a) The payment structure for ancillary services; and
b) The procurement process for ancillary services

3.2.3.1. Reserve

The ancillary service of particular relevance is termed 'Operating Reserve' and covers FCAS (spinning reserve and load following). Operating Reserve is part of the Operating Margin which is the amount of reserve (provided by additional generation or demand reduction measures) available above that required to meet expected system demand. The capacity providing operating reserve is required to be flexible and controllable to a certain extent and therefore not all generating capacity can fulfil the function of Operating Reserve.

Due to the relatively small size of the system there is a heavy emphasis on Operating Reserve and, as the penetration of wind generation increases, the requirement for Operating Reserve is also likely to increase. Given the relative importance of Operating Reserve it was decided that the provision of Operating Reserve should be directly incentivised through an individual payment mechanism based on regulatory approved rates.

However, it was also considered that the establishment of a fixed rate approach may not provide sufficient market incentives to promote competition between reserve providers, recognising that the reserve requirements (and associated costs) vary during each day. For example, during the night some plant may remain connected to avoid restart costs and the amount of reserve capacity then may exceed the system requirements without any system operator intervention; however extra reserve generation capacity may be required during the day peak. As a result a reserve remuneration scheme will be introduced based on a fixed minimum regulated rate, but also include a variable proportion that the system operators can adjust depending on system requirements and participants' availability. The variable rates will be subject to regulated caps. The envisaged hybrid fixed/variable rate scheme will allow the system operators to increase or decrease payments based on the provision of reserve from the market participants and the specific short-term system requirements

Penalties will also be applicable to participants which, having received a reserve payment, fail to deliver the required level of performance. These regulated penalties will be proportionate with the payments received and will be used to reduce the funding needs of reserve payments, and ancillary services in general, from general customers.

3.2.3.2. Procurement of Reserve

It was decided not to adopt a tendering approach in the procurement of operating reserve. The number of market participants was considered insufficient to ensure competition in the provision of reserve and therefore it was considered that the benefits of tendering might be outweighed by implementation costs.

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3.2.4. System Operator Incentives

Overall it is considered that incentivising the system operation is desirable as it has the potential to reduce the overall cost to the consumer. The efficiency of the system operators in determining the required level of reserve and the payment scheme will be evaluated as part of a larger incentive scheme.

3.2.5. Summary of Irish Experience

The electricity market in Ireland has some strong similarities with the market in the SWIS and therefore provides some pertinent lessons. A key message is that the size and configuration of the market dictates what might be achievable – a market with a dominant, state owned incumbent generator and supplier is unlikely to provide a robust environment against which to competitively procure ancillary services.

Incentivising the behaviour of market participants and the system operator also arises as an important issue. For the market participants, incentivising behaviour to comply with the relevant Grid Code requirements through a system of payment penalties and rewards has emerged as an important tool to ensure compliance than the ultimate threat of licence revocation. For the system operator it is now acknowledged that the development of an incentive mechanism is the most appropriate way of actively promoting the most efficient management of the system.

A report[11] into the moratorium on new generator connections in Ireland made the following recommendations for other electricity jurisdictions considering a similar approach to that adopted in Ireland.

1. The technical concerns underpinning the moratorium could have been addressed earlier as the challenges were foreseen in 2000. In particular, more effective engagement between the TSO and turbine manufacturers would have facilitated the early development of dynamic models and wind farm Grid Codes which would have resulted in a more controlled growth of wind power in line with revised requirements;
2. Projects could have been allowed to continue at the developer's risk. For example, when the dynamic model for a wind turbine is finally available and validated, in the event that it shows that the turbine will not perform as required, the connection agreement would be revoked. This risk would in turn be passed on to the wind turbine suppliers. In the Ireland case, it is not clear whether the developers would have been willing to accept this risk, however one advantage is that there would be

[11] O Gallachoir, B.P., Garnder, P., Snodin, H. and McKeogh, E.J. (2007) 'Wind energy and system security – the grid connection moratorium in Ireland', Int. J. Energy Technology and Policy, Vol. 5, No. 5, pp633-647.

significant commercial advantage for a wind turbine manufacturer to demonstrate compliance;

3. Developments could have been allowed to continue in geographical areas where low-voltage ride through and the other concerns are not anticipated to have a significant impact. For example, where a transmission system fault will not result in unacceptable loss of wind generation. Additionally, the TSO could have published the available 'headroom' in each of the areas so that developers can assess when fault ride through is likely to be an issue.

The lessons learnt from Ireland and the progress made with the Grid Code and dynamic models for wind turbines should result in the process of dealing with increasing penetrations of intermittent generators in other jurisdictions being easier.

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4. The Work Program

The scope of work for the Work Program has been separated into Work Packages with the aim of grouping elements of work that are considered to be closely related. As previously indicated, it is possible that there are both technical and market solutions for the challenges associated with each issue. A thorough investigation into the possible solutions with appropriate references to other electricity jurisdictions where these have been applied and the outcome is required. Further, as there are imminent challenges to ensure the continued development of viable and commercial generation while sustaining the operation of the market and the power system, each work package requires consideration of the immediate challenges and solutions within the existing frameworks together with consideration of sustainable long term solutions. Consideration of a staged approach to the Work Program should be made and a methodology developed to support the development and investigation of the issues.

The work packages are described below.

4.1. Work Package 1 – Impacts Resulting from State and National Policy

The future generation mix in the SWIS and the level to which intermittent generators penetrate the market will depend on the behaviour of the market to targets and initiatives set in state and national policy.

The Federal Government is leading the setting of policy for renewable energy solutions and as such, the WA government has decided to cease development of a specific WA renewable energy scheme. The Federal Government is using two broad-based mechanisms that will promote the introduction of renewable energy, namely the Carbon Pollution Reduction Scheme (CPRS) and the Mandatory Renewable Energy Target (MRET). Both schemes act to incentivise renewable (including intermittent) generation development by effectively normalising the higher cost typical of renewable generation with conventional plant. The intention of any renewable energy policy is that energy from renewable energy sources will displace that of conventional fossil fuel sources. One of the resultant impacts is that electricity networks and markets will need to adapt to allow this to occur. The national programs will serve to provide a substantial, broad-based incentive to invest in new low emission and renewable energy generation capacity in the SWIS. The market should take a neutral stance and provide incentives that reflect and reward each project and technology's interactions with the market according to its merits.

Wind generation is the first renewable energy resource other than hydro that has achieved substantial grid penetrations within electricity networks worldwide and the SWIS is no exception. It is also considered likely that wind will remain a major renewable generation source for at least the next decade or two. As a consequence, managing the connection of wind to the grid is the frontrunner to addressing the issues associated with intermittent generation.

An analysis of likely outcomes of the policy and what this will bring in terms of the generation mix is necessary in order to determine the priority and timing of tasks to ensure that the SWIS grid and market adapt at a pace congruent to the rate at which penetration levels rise.

As the policies will have an impact over time, it is important to consider both the short and longer term issues for the electricity grid and market. While the issues may be the same in both terms, the appropriate mitigation measures may differ substantially and evolve over time and will need to be investigated thoroughly.

Initially, the consideration and focus should be on rules and policies that presently exist within the SWIS that may act as an impediment to intermittent generators locating in the SWIS. Modelling the impacts associated with the changing generation mix over time and the subsequent identification of risks, costs and impediments associated with increasing levels of intermittent penetration should be considered. A further consideration is that with increasing levels of intermittent generation, consideration of the possibility of a system wide network upgrade and what that would mean in terms of infrastructure, costs and timeframes should be undertaken.

Consideration of policies that encourage dispersed intermittent generation and renewable generation that is more controllable (e.g. geothermal, biomass) and the associated economic impacts of these policies should be undertaken. Potential transmission network upgrades should also be considered in terms of the economic analysis. Detailed modelling of renewable generation scenarios will need to be undertaken to demonstrate the impact on the SWIS and WEM in the short and long term.

Consideration of technically achievable and cost-effective strategies and mechanisms to support the predicted growth of intermittent generators should be fully explored in the context of the SWIS grid and market. A key outcome of the study will be to identify and provide strategies for addressing the impediments to the efficient penetration of renewable energy generation in response to Commonwealth and State Government policy setting.

4.1.1. Estimated Timeframe and Resource Requirements

It is anticpated that Work Package 1 will require input from specialists in the following fields of competence:

- Energy market economics and modelling;
- Policy, regulation and pricing in competitive electricity markets;
- Renewable energy resource assessment and analysis; and

- Planning of power system networks including both technical and economic aspects;

It is anticipated that consideration, review, modelling, investigation and recommendations to the issues and challenges associated with Work Package 1 would take between 4 and 6 man weeks, however the outcome will be heavily dependent on the information available at the time of the review (i.e. State and National policy documents etc).

4.2. Work Package 2 – Service Type Capacity and Reliability Impacts

The existing Reserve Capacity Mechanism (RCM) within the SWIS market recognises the contribution intermittent generators make towards system security and capacity, however, as penetration levels rise, it will be necessary to determine the contribution that intermittent generators make towards satisfying the requirements and the appropriate method for remunerating the capacity they provide.

The RCM presently procures capacity that is compliant with the Market Rules (Chapter 4). While there are other methods for procuring capacity, namely, Ancillary Services, Network Control Services and reduced network access charges, the focus of this Work Package is the procurement of capacity to meet forecast demand (presently through the RCM) and the contribution intermittent generators can make.

It should be noted that the purpose of the Work Package is to identify capacity services required as opposed to identifying and or specifying a technology that can provide a particular service. The intention of the market is not to drive the implementation of technologies, but rather the provision of the technical services required. The procurement of services is mandated in Technical Rules and requirements for capacity include ramp rate and fault ride through (i.e. must meet minimum defined technical levels).

Consideration should be given to what capacity the system requires in order to function securely and how this capacity should be procured. While the existing RCM is administered against a mandated set of requirements, this may not be the most ideal approach as intermittent generation penetration increases. Alternatives approaches such as procuring different service types with different service levels or redefining the minimum mandated technical levels and creating a market for a higher level of service should be considered. Suitable structures for providing suitable capacity types and the procurement of this capacity should be considered.

A key consideration when comparing the scope and provision of capacity is whether the requirements identified should be categorised according to the service type required or the technology that provides them. This is important in the SWIS where technology type is important in such a relatively small system and clearly had a big impact following the event on the SWIS on

28 November 2007[12]. This event was instigated by the disconnection of a large generator and resulted in the inability of the system frequency to recover without shedding load.

For any service or technology type identified, consideration should be given to whether it is necessary or appropriate to apply a financial incentive to ensure the adequate provision of the service for system security. As part of this investigation an important consideration is whether or not the provision of the particular service is mandatory for generators. It is generally considered that it is appropriate to incentivise provision; however, appropriate penalties should be considered for non delivery.

If it is deemed appropriate to incentivise the supply of a particular service, its financial significance should be considered and hence whether it is more appropriate to treat it separately for procurement purposes or bundle it into a set of services with one payment.

Consideration should also be given to the issue of who pays for increasing volumes of reserve that arise with increasing amounts of intermittent generation penetration. While it may be considered appropriate to implement a 'causer pays' system, this may run in direct opposition to renewable targets and hence alternatives should be examined. Work Package 1 considers the likely future generation mix under a number of situations that may arise out of national and state policy.

Another consideration is how the services will be procured. There are a number of issues to be addressed when considering procurement:

- In principle each service should be procured through a market mechanism. This is the case with the existing Reserve Capacity Mechanism; however, this may need to be revised or complementary mechanisms introduced (i.e. the RCM does not necessarily have to change; however, a separate procurement mechanisms could be introduced. For example, the Network Control Service procures location specific generation and separate Ancillary Services are procured through alternative mechanisms). The integration of procurement of required services into the RCM may or may not be appropriate and the benefits and drawbacks (and therefore alternatives) should be investigated thoroughly;
- The complexity and cost of implementing the procurement option should be commensurate with the cost of the service and the potential benefits;
- The procurement mechanism should promote adequate supply of the service in an operational timeframe; and
- It must be practical to calculate and settle.

[12] WA Independent Market Operator, Investigation into the power system incident of 28 November 2007, March 2008, PA Consulting

With potential changes to the Technical Rules in order to account for intermittent generators, there is the possibility of separation between the Technical Rules and the market with respect to a constrained and unconstrained network (the SWIS currently works on the basis of unconstrained access). For the purpose of determining the appropriateness of reserve capacity requirements and the contribution to reserve capacity, consideration of factors such as network diversity should be made. Output during peak periods, the geographical dispersion of generators and the relationship between fluctuations in demand and intermittent generation should be considered. Additionally, apposite consideration of the characterisation of wind reserves and the method to which this characterisation should be applied to the assessment of reserve capacity should be made.

It is the intention of the Work Package that the outcome will be recommendations that address how intermittent generators should be assessed with regard to their contribution to capacity (RCM) and the necessary revisions to the present certification methods and / or complementary mechanisms that should be introduced to appropriately account for the contribution that intermittent generators make.

4.2.1. Estimated Timeframe and Resource Requirements

It is estimated that Work Package 2 will require input from specialists in the following fields of competence:

- Energy market economics and modelling;
- Policy, regulation and pricing in competitive electricity markets;
- Modelling and operation of generators, transmission and distribution networks;

It is anticipated that consideration, review, modelling, investigation and recommendations to the issues and challenges associated with Work Package 2 would take between 6 and 8 man weeks.

4.3. Work Package 3 – Frequency Control Services

The provision, type and amount of Frequency Control Services required to facilitate the secure and reliable operation of the SWIS by the system operator (System Management) with increasing penetration of intermittent generation is uncertain. International studies have shown[13] that system balancing (load following in the SWIS) costs increase as a result of the need to schedule additional response and reserve plant to manage unpredicted fluctuations on the timescale from minutes to

[13] The Costs and Impacts of Intermittency: An assessment of the evidence on the costs and impacts of intermittent generation on the British electricity network, UK Energy Research Centre, March 2006

hours. The costs associated with system balancing (load following) should be ultimately passed on to electricity consumers (perhaps through causer of increase) and should be procured efficiently and be sufficient to meet the requirements of the network.

It will be important to take into consideration the network diversity and characterisation of intermittent resources and the role this plays in determining the requirements for energy balancing.

Correctly determining the service requirements (quantity and type) is an important consideration from both a technical and market perspective as significant increases in intermittent penetration will naturally lead to greater amounts of energy being dispatched for balancing (load following) which will be reflected in the total cost to generate electricity.

Previous studies on the SWIS and international networks have shown that with low levels of intermittent penetration, output variability can be managed satisfactorily under the existing requirements established for conventional generators (the spinning reserve requirement in the SWIS covers the largest unit and included in this is a provision for load following services). An assessment of whether these measures are adequate for the present generation mix and with the forecast penetration of intermittent generation in the short and long term is required. The investigation should identify the point at which penetration levels dictate the requirement for changes to the existing arrangements (i.e. when the Frequency Control Services of spinning reserve, load following and load rejection need to be altered with respect to type and quantity). Particular attention should be given to the potential exacerbation of existing overnight minimum load operational issues that may result from increased penetration of intermittent generation and the impact this will have on the type and quantity of frequency control service required. Detailed modelling of generation and demand scenarios will need to be undertaken to demonstrate the impact of any suggested and recommended alterations.

Consideration of the available mitigation measures to intermittent generation variability will need to be undertaken. There are presently a number of market rules in WA that are intended to provide services for managing output swings. Understanding and determining the requirements for these services is a critical factor as intermittent generation penetration increases. Consideration of the maximum credible simultaneous change in output and the response time for the services to maintain network stability is required. Consideration of the response times and of the criteria for maximum credible change is necessary. It will be necessary to understand and take into account the proposed location of intermittent generators on the network in determining the criteria for maximum credible change. Consideration of this could be used during the characterisation of wind activities mentioned in Work Package 2 as wind farms located in the same geographic area may be subject to a credible change in output (positive and negative) due to their proximity to one another.

The WEM rules currently require the procurement of immediate and fifteen minute frequency control services. These services are procured by System Management (and approved by the IMO) and used by to manage generator output swings for conventional and intermittent plant. In light of the increasing penetration of intermittent generation, determining the optimum level of the each service needs to be performed. As the penetration of intermittent generation increases, the requirement to accurately predict output becomes critical. This is both a technical and market issue. From a technical perspective, correctly predicting wind output can assist System Management's ability to maintain system security as they will be able to dispatch generation with a reasonable degree of foresight. This in turn will help reduce the requirement for ancillary services which should result in lower costs for these services in the market. As such, consideration of the forecast modelling work currently underway by Western Power will be a necessary input into determining the optimum levels required. It is envisaged that as penetration levels increase, highly accurate forecasts of wind farm output will tend to reduce the requirement for immediate frequency control services. The communications requirements for provision of information from the intermittent generators to System Management are addressed in Work Package 4.

The underlying principle for the development of additional performance incentives should be that there should be no increase in cost to the electricity consumer. A generator performance incentive scheme of withholding (other services may be defined eg NCS) services payments, coupled with a penalty mechanism which will ake the form of an amount charged to the unit which is a multiple of the rate paid for performance should be considered.

The cost associated with the provision of frequency control services needs to be considered in light of the increasing penetration of intermittent generators and indeed consideration of whether intermittent generators can be used to provide these services is warranted. Consideration will need to be given to the allocation of costs and benefits to participants in a way that is reflective of the costs and benefits each provide to the industry.

Due to the low demand at night on the SWIS and the inflexible operation of the existing plant, intermittent generation may need to be displaced at night. Currently, the market is structured such that the wind generators continue to be remunerated when they are constrained at the full value of output. Mechanisms that allow for the optimal decision to be made with respect to the reduction of generator output (i.e. whether it is optimal from the market perspective to reduce output from dispatchable or intermittent plant) need to be considered. For example, one such mechanism may be that the curtailment of intermittent generators be considered a frequency control service and be used for the purposes of reducing output at times of minimum system demand when dispatchable plant cannot economically reduce its output. The requirements for curtailment and the implications for the network and market should be considered thoroughly. Any conclusions must be supported by proposed market mechanisms for making assessments on whether intermittent or dispatchable generation should be curtailed.

Geographic diversity of generation and the network reinforcements required to support high levels of intermittent generation together with consideration of cost sharing and differential use of system charges will be required. An objective of the Western Australia Electricity Code (ENAC 2004) is to ensure a balance between the interests of new connection proponents and other network users is achieved. For network augmentations that satisfy the requirements, the SWIS Network Operator is required to undertake the investment and recovers the cost through charging a use of system tariff to all users. Additionally, charging proponents a cost reflective amount for new connections would provide a mechanism to incentivise generation at locations where it is required and that could reduce network costs and should be investigated. There is currently a requirement in the SWIS for the Network Operator to reduce the use of system charge for a distributed generator where it leads to a cost reduction in costs for the Network Operator. Implementing this on the SWIS network for all generators may provide incentives to investment and economic efficiencies for the market as a whole and should be considered.

4.3.1. Estimated Timeframe and Resource Requirements

It is estimated that Work Package 3 will require input from specialists in the following fields of competence:

- Energy market economics and modelling;
- Policy, regulation and pricing in competitive electricity markets;
- Modelling and operation of generators, transmission and distribution networks;
- Planning of power system networks including both technical and economic aspects;
- Assessment of stability of networks and implementation of remedial measures;
- Assessment of interconnected power system capability;
- Assessment of issues associated with the integration of embedded generation into distribution networks;
- Assessment of issues associated with the connection of generators to transmission network;

It is anticipated that consideration, review, modelling, investigation and recommendations to the issues and challenges associated with Work Package 3 would take between 12 and 16 man weeks.

4.4. Work Package 4 – Technical Rules

As intermittent generation penetration increases within the SWIS, the appropriate mitigation measures for the SWIS to ensure network stability against the known issues associated with intermittent technology are uncertain. This issue requires significant consideration in order to resolve as it may be difficult to determine the appropriate mechanisms and strategies that support the integration of intermittent generation at a reasonable cost to developers while ensuring credible contingencies do not compromise the security and integrity of the network. New proponents entering alongside existing ones and the uncertainty as to which project in the 'connection queue' will be developed adds further complication and rules that are overly stringent may well be prohibitively expensive for generators to comply with.

The issue associated with the Technical Rules present themselves both in the short and long term. While the issues may be the same in both terms, the appropriate mitigation measures may differ substantially and evolve over time and will need to be investigated separately. The principle challenge that needs to be considered is that as energy penetration levels increase up to and over 20 percent (depending on the impact of state and national policies on penetration levels are addressed in Work Package 1), measures such as limiting ramp rates for active power, procurement and use of additional control services (Work Package 3) and mandated communications to and control by the system operator (System Management) may be required.

Consideration of the current technical rules requirements and prospective revisions to better deal with the connection of wind farms is required. Specific attention should be paid to the following areas:

- Fault ride through capability. If the fault ride through for intermittent generation is not appropriate for the system, there is an increasing risk that a transmission network fault could lead to a chain reaction of events that has catastrophic consequences such as a system black-out. Equally important to consider is that if the fault ride through requirements are too stringent, the cost of compliance for intermittent generators may be too onerous and the targets set by the Government may not be achieved;
- Frequency requirements. Consideration of acceptable limits of generator performance across a range of system frequencies is required. Additionally, consideration of frequency control including the capability of operating each intermittent generator at a reduced level, following specific power frequency requirements and controlling ramp rates of active power should be undertaken;
- Voltage requirements. Consideration of the ability for an intermittent generator to remain connected at maximum power output for step changes in transmission voltage and to have a continuously active voltage regulation system that modulates the reactive power output to change the voltage set point at the connection should be considered; and
- Communications requirements. Consideration of the data and control requirements for wind farms such as to provide signals and controls including meteorological data, availability data, MW displacement data and frequency response system settings is

required. Consideration of the importance, costs and likelihood of the ability for wind farms to receive signals from the TSO and act accordingly should be undertaken.

Consideration should be given to the technical rules and market perspective on conditions requiring the output of the intermittent generators to be constrained for system reasons. This is addressed in detail in Work Package 3.

System studies will be required to understand the impacts of any proposed changes to the Technical Rules the effect this will have on the generators connected. Consideration of the present critical clearing times and the full impacts associated with changes to these times will be required.

Consideration should also be given to whether connection agreements can be prioritised and negotiated on the basis of providing a benefit to the market and users due to their location in the network. It may be appropriate to consider establishing geographic boundaries within which different mitigation measures are required. This may facilitate the efficient connection of generation onto the network, however, due consideration to any potential deep network reinforcement should also be considered. Additionally, consideration of exemptions from the fault ride through requirements in certain circumstances should also be undertaken. Reference and investigation of other jurisdictions and in particular the NEM should be undertaken; however, the mitigation approach should be supported by modelling specifically for the SWIS.

In conjunction with the studies to determine mitigation measures from a technical perspective, apposite consideration of market based alternatives to the fault ride through issues, such as the payment by an intermittent generator of a spinning reserve charge to cover the risk associated with disconnecting during a fault should be considered.

It should be noted that there is little likelihood of retrospective rule changes to the technical rules and as such, changes to the network connections of existing generators is unlikely. As noted above, the issues associated with the technical rules present themselves both in the short and long term and while the appropriate mitigation measures may differ, consideration should be given to measures that are conducive to any transitional and long-term arrangements likely to be required.

4.4.1. Estimated Timeframe and Resource Requirements

It is estimated that Work Package 4 will require input from specialists in the following fields of competence:

- Planning of power system networks including both technical and economic aspects;

- Assessment of stability of networks and implementation of remedial measures;
- Assessment of interconnected power system capability;
- Assessment of issues associated with the integration of embedded generation into distribution networks;
- Assessment of issues associated with the connection of generators to transmission network;

It is anticipated that consideration, review, modelling, investigation and recommendations to the issues and challenges associated with Work Package 4 would take between 8 and 12 man weeks. This estimate excludes any proposed changes for a new Technical Rules.

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