Session 2

# Connecting Renewable Generation in Weak Networks

27 November 2018

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# Looking back to 2017

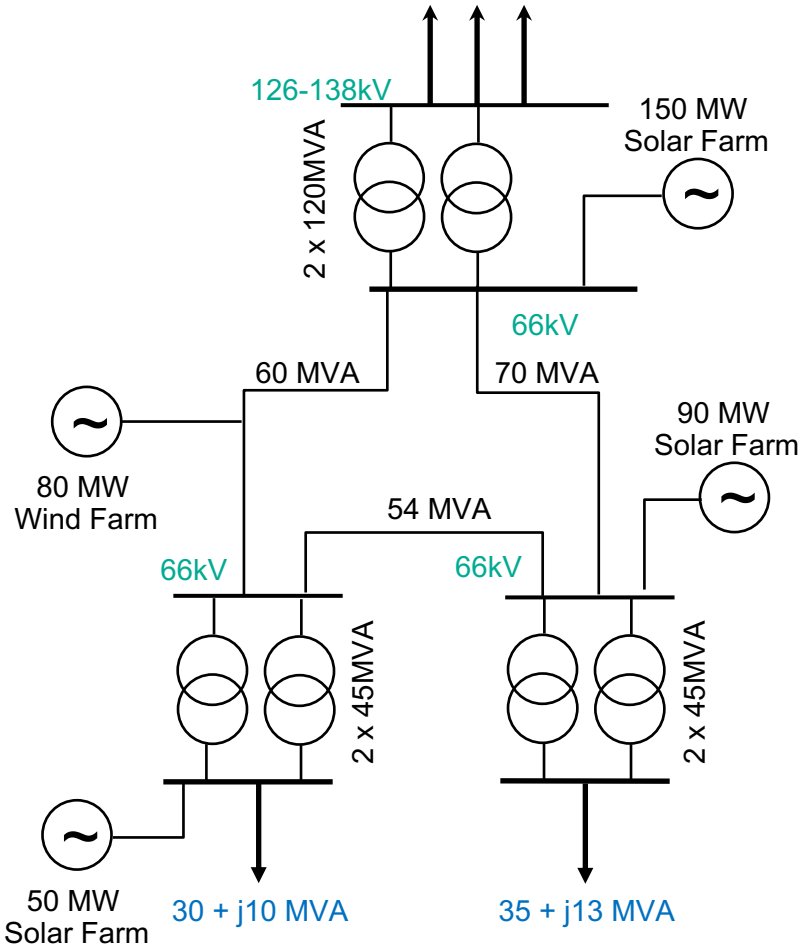
*"Operational Issues When Connecting Renewable Generation" 7 September 2017*

## Implications for weak networks:

- Power Quality impacts
- Protection mal-operation
- Small signal and transient stability
- Islanded voltage and frequency control

## System Security Obligations

> An ongoing need for:
  - special protection schemes
  - a subsystem nodal runback system (*the black box*)
  - management of short circuit ratios



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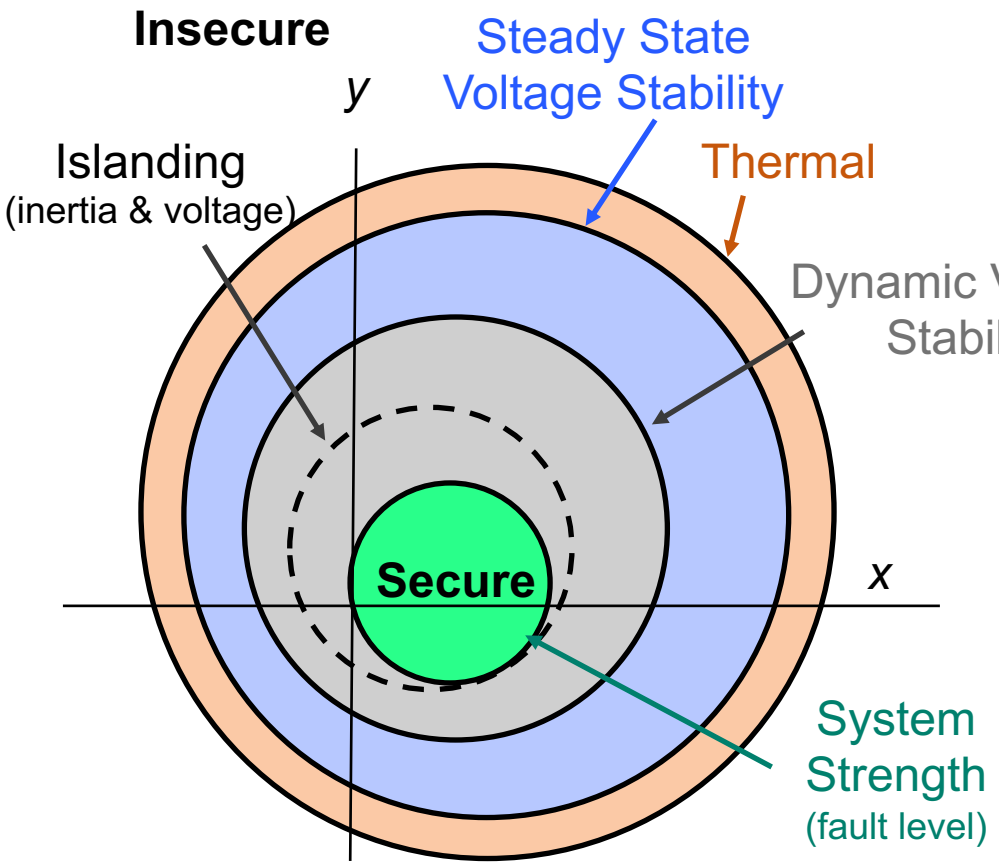
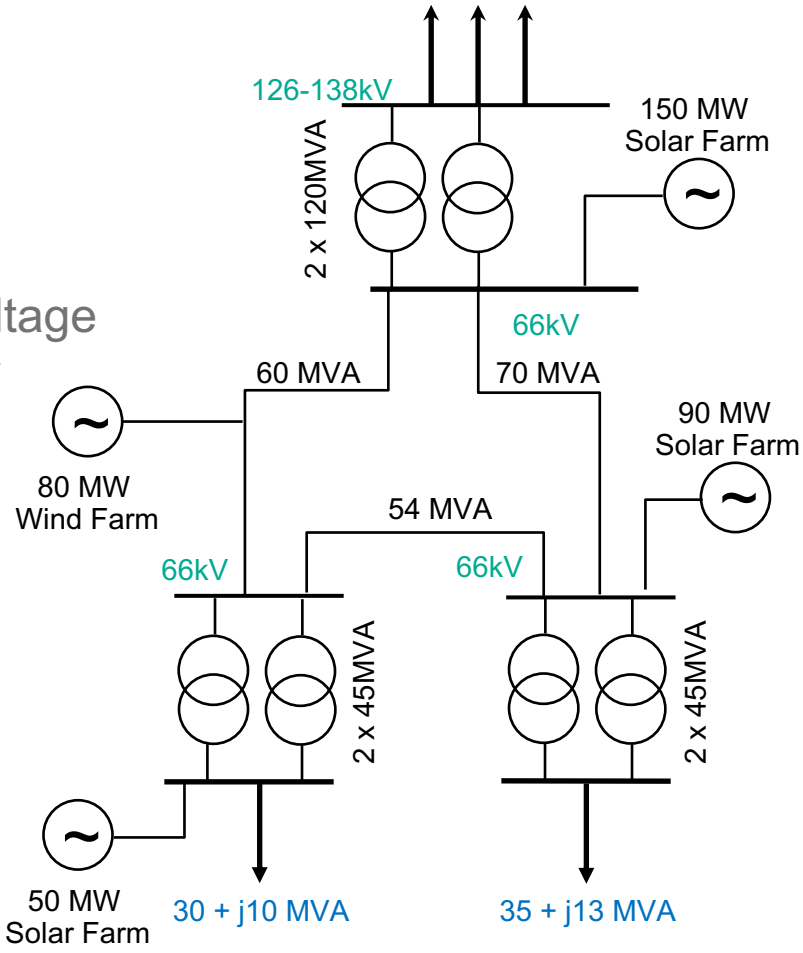
# The Technical Envelope



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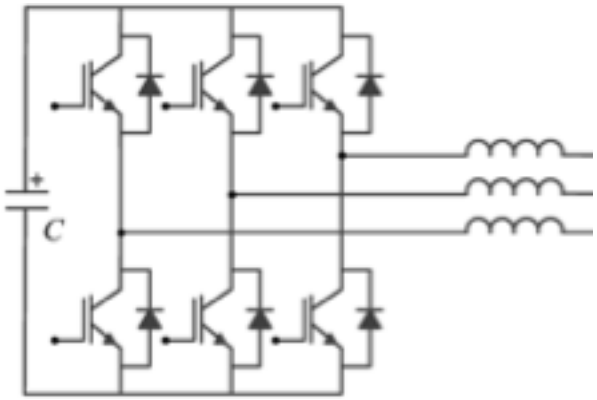
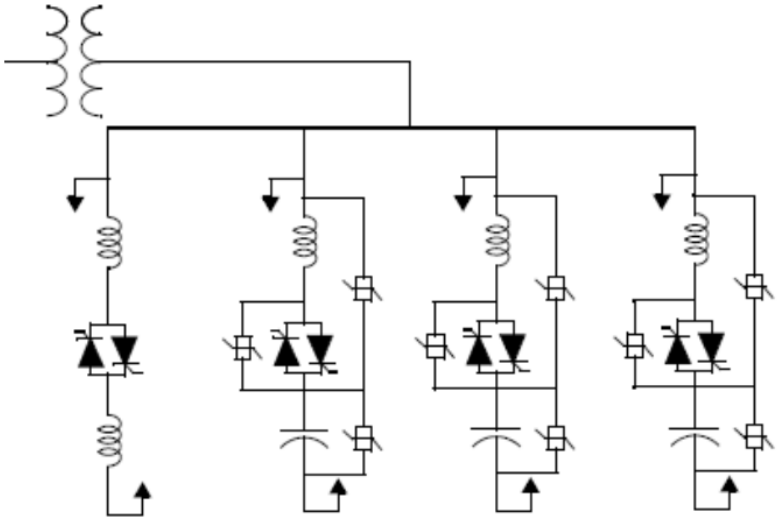
# Impact of System Strength

## Inverter-Based Generation

- Require a strong system to maintain stability (high 3-Ph fault levels)
- Fault level must be allocated to individual inverters and cannot be shared
- Susceptible Equipment:
  - Energy storage inverters
  - STATCOMs
  - SVCs
  - Solar Inverters
  - Asynchronous machines



## The Common Solution:

- **Synchronous Condensers** (Syn Cons)….
  - Improve the 3-Ph fault level
  - Suffer from transient instability if they lack inertia
  - Alternate options: a large three phase machine with added rotating mass (flywheel)



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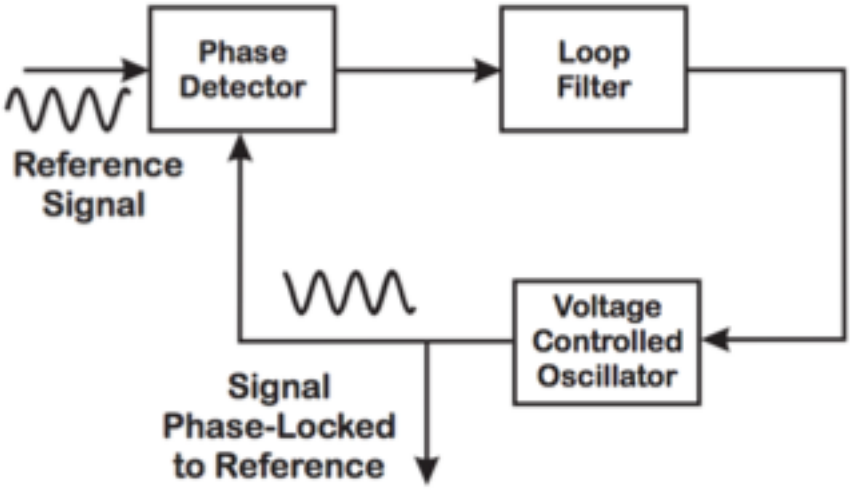
# Impact of System Strength

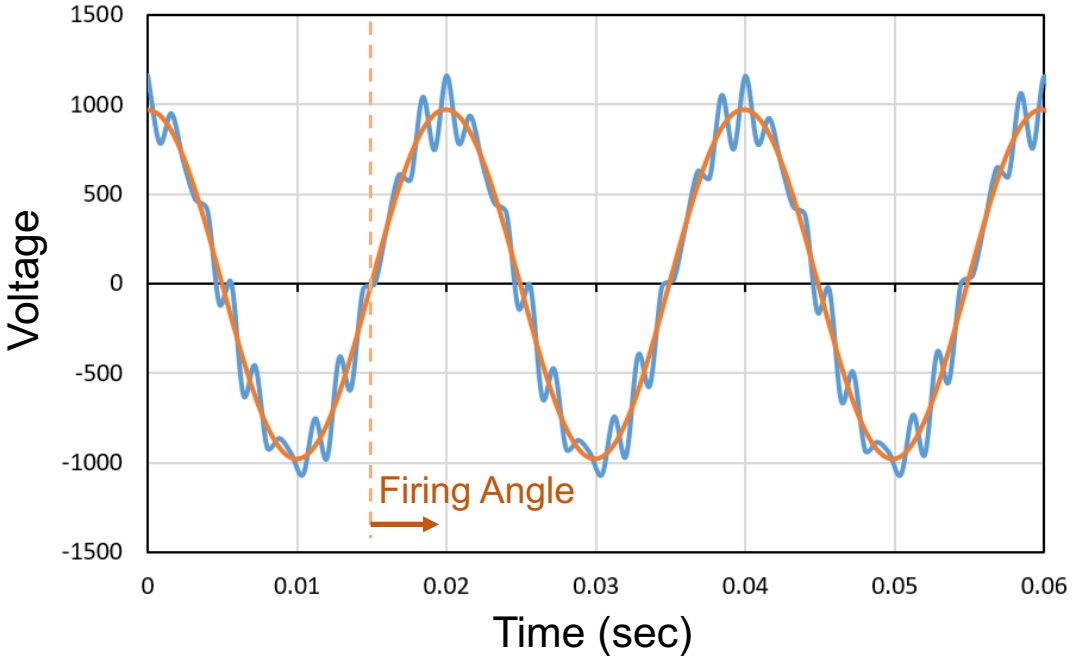
## Phase Locked Loops (PLL)

- PLL's are used to
  - derive the frequency and phase
  - Replicate an input waveform
- Adjusting the voltage angles
  - controls the MW output
- Adjusting the voltage magnitude
  - controls MVAr output




## Types of Phase Locked Loops

- Three single phase PLL's
  - Then extract the positive sequence
- A single three-phase PLL
  - *abc* to quadrature *dq* transformation
  - Requires the measurement of system frequency.



# Impact of System Strength

## Types of Three-Phase PLL's

- The Synchronous Reference Frame PLL
- 3-phase 'Enhanced'-PLL
- Synchronous reference frame with lead compensation
- The windowed synchronous reference frame
- Double second-order generalised integrator
- Decoupled double synchronous reference frame

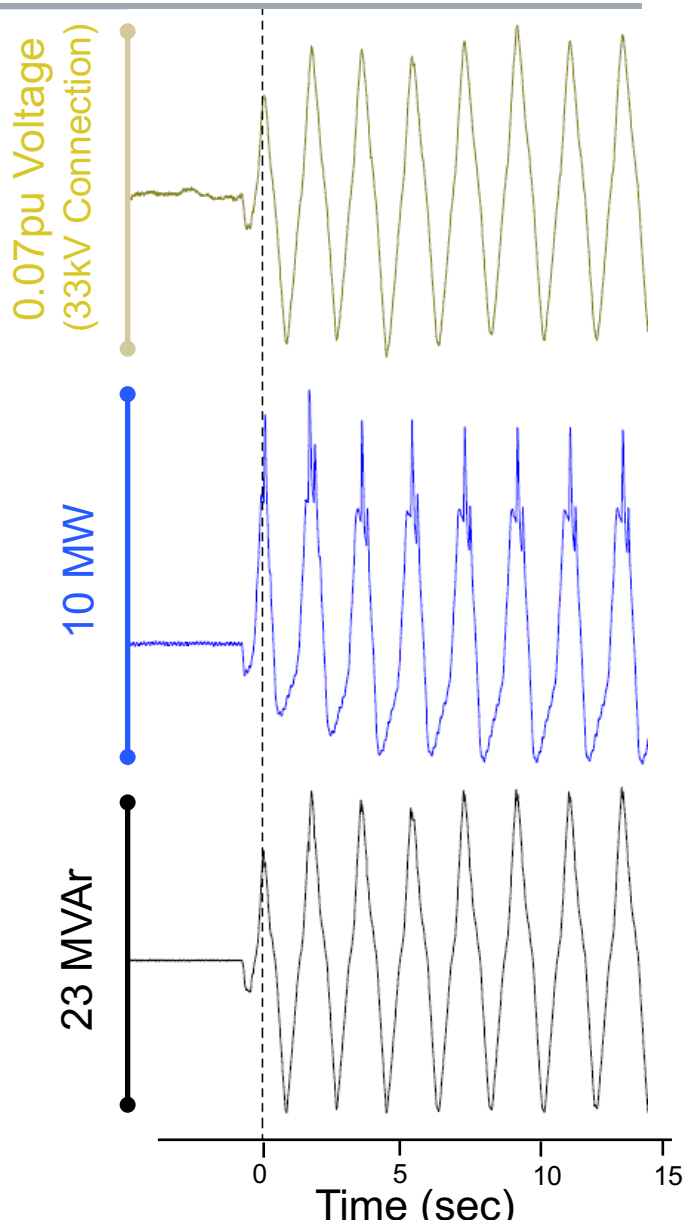
*… and many more*

## When Things go Wrong

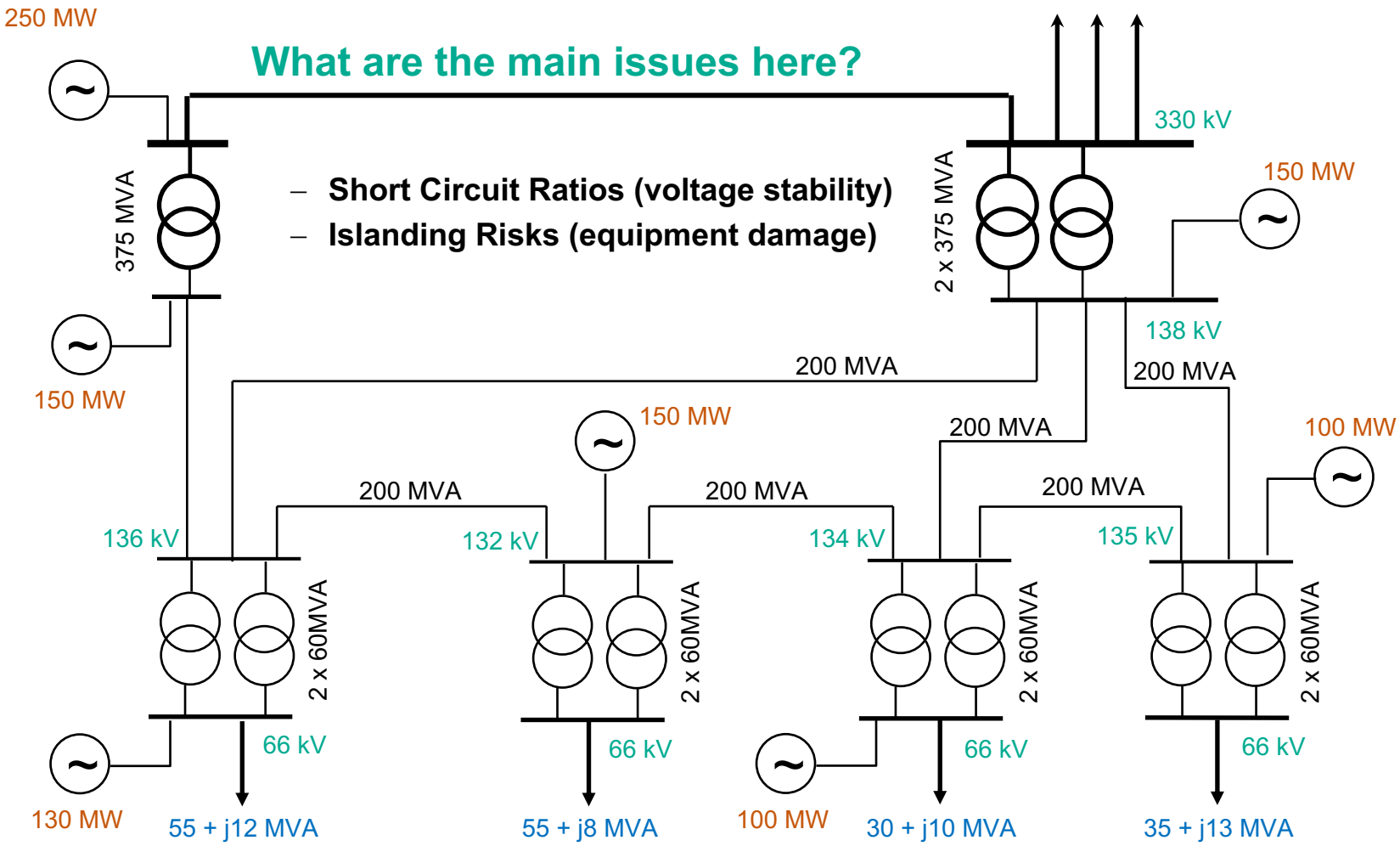
> PLL's work well where there is a good signal to noise ratio.

> They are susceptible to

- phase angle changes
- frequency changes
- Amplitude changes
- Unbalanced inputs
- Load type, if suddenly islanded
- **Low fault level (signal to noise) conditions**



# Application within Weak Systems



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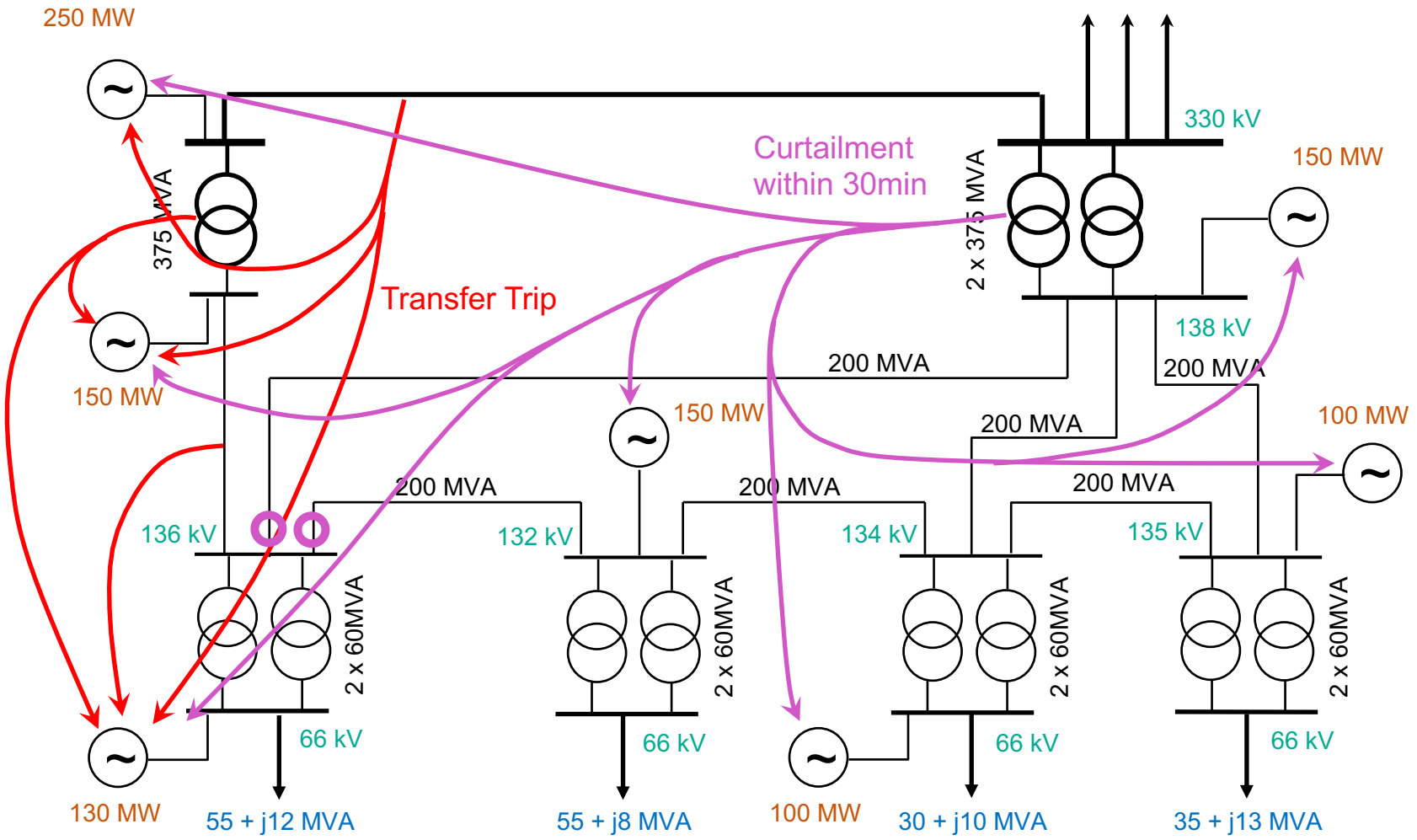




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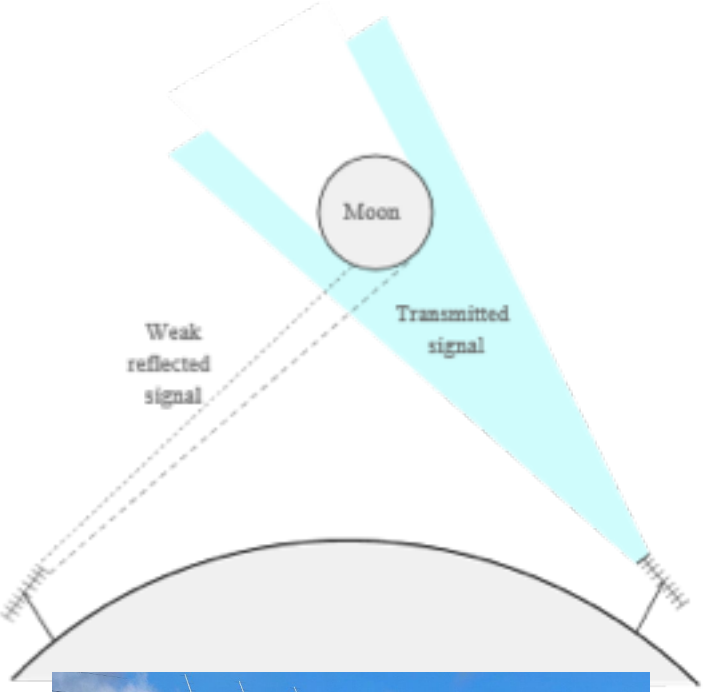
# Working with Low Signal to Noise Ratios

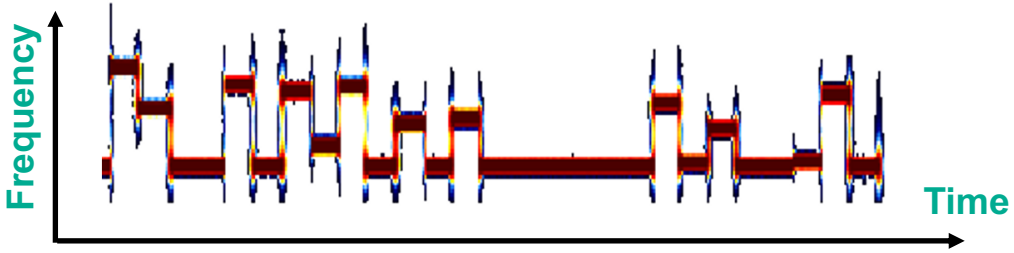
## Operating under low Signal to Noise Ratios

- WSJT Communications Protocol
  - Used for moon-bounce radio communications
  - JT65B:
    - Transmission begins 1s after the UTC minute
    - Transmission finishes 47.8s after the UTC minute
    - Transmission and receive operations alternate each minute.
    - 126 time intervals, each of length 0.372s
    - The signal is a sinusoid at one of 65 pre-defined frequencies




## The importance of Time Synchronisation

- JT65 will not decode if the time references are not aligned



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# System Strength and Islanding

## Proposed Solution

- Remove the PLL from grid connected inverters
- Replace these with an external synchronizing reference
- Reference voltage should not be modulated by inverter based generation
- A requirement for duplicated communications links with GPS as a backup

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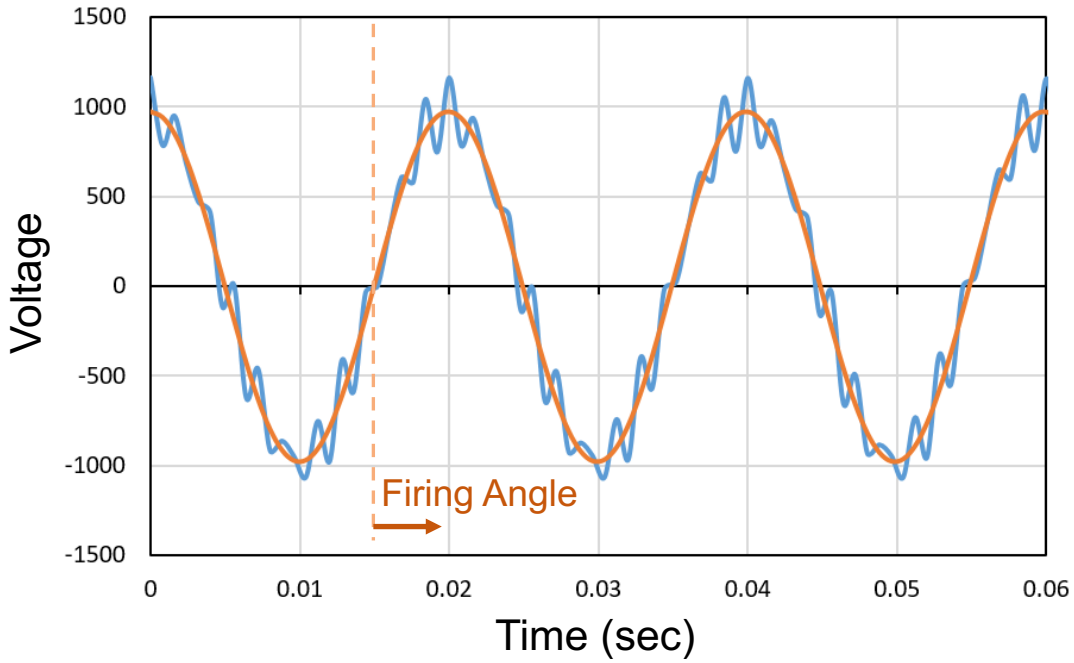




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# Questions?



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