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Coding Challenges

GADS Wind Training Module 16

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RELIABILITY | ACCOUNTABILITY

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Content

- In this module we will explore:
  - Weather
    - Ice
    - Turbulence
    - Temperature
    - Lightning
  - Failed protection
  - Plant Outages
  - Overlapping events
  - Replacements
  - Refurbishment
  - Repower
  - Environmental

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Weather

Wind Turbines (WTG) are often installed in areas where they experience extreme weather conditions. When dealing with coding issues related to weather the turbine design and operating specifications need to be taken into account. These define the operating envelop for the WTG.
Some examples:

- Wind speed above or below design – categorized as RUTH
- Ice – Increases structural loads leading to delayed pitching and braking time
- High turbulence – shows up as yaw, pitch and vibration faults that are beyond the turbines ability to control
- Temperature extremes – Winter polar vortex to high desert temperatures in south Texas
- Lightning – Plays with transmission lines causing brown outs to outages

- Wind turbines are designed to operate within specified design criteria. Often the operating environment extends beyond these limits and causes outages. How these outages are classified can be challenging at times.
- Wind turbines operate within a wind envelope called the power curve. As wind speed increases power output changes in a non-linearly. If you double the wind speed the output increases 4 times and the loads on gearboxes can increase as much as 8 times. Small increases in wind speed have large impact on the turbine. Outages outside the turbine power curve are classified as RUTH.
- Ice adds weight to turbine structures (blades / nacelle). The ice can change the aerodynamics and balance of the rotor causing abnormal vibration. Ice can also cause physical damage to sensors causing outages.
- Turbulence is defined as the rapid change of wind direction and speed. Often thunderstorms, storm fronts, column winds and terrain cause abnormal turbulence. This leads to abnormal shaking or pushing the nacelle in abnormal positions.
- High and low temperature can cause electronics to fail or miss-operate. Oil and grease can become ineffective.
- Lightning – can strike turbine blades and overwhelm lightning protection. Lighting can also impact the grid causing outages, momentaries or brown outs.

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Weather

Weather is coded as an OMC event. Care must be taken when coding weather events as the tendency is to blame everything on weather. There should be clear linkage between the weather event and the fault or failure. Also, the events occur as clusters of the same faults not individual faults.

Examples of good coding:

- Icing event – Braking time to long – increased mass of ice delays braking
- Icing event – Pitch faults – Ice physically interferes with pitching between the blade and the hub
- High Turbulence event – Yaw run away – High winds changing direction with enough force to push the nacelle around

Examples of bad coding:

- Yaw run away during an icing event
- Clogged gearbox oil filter during high turbulence
- High generator bearing temperature during lightning storm

- Weather events usually impact a large portion of the wind plant and can cause various symptoms. The turbine outages tend to occur in clusters with the same general type of fault. The tendency is to attribute all events to the weather condition when this is usually not true. There should be clear linkage between the event and the outage. You should be able to indicate why this weather event caused this type of outage. Without clear linkage the event should not be attributed to the OMC weather event.
- Good Coding – During an icing event a large number of braking time to long faults occurred. Ice increases the mass of the rotor by as much as several thousand pounds. This increases the braking energy or time required to stop the rotor leading to excessive braking time.
- Good Coding – During an icing event a large number of pitch faults occurred. Ice can build up between the hub and blades interfering with proper pitching. Sometimes the ice can build up in the junction between the blade and hub, knocking out pitch sensors.
- Good Coding – A large number of yaw run away events occurred during high turbulence when a thunder storm passed through the park. Yaw run away means that the nacelle was pushed out of the wind because of high side loads overcoming the yaw dampening system.
- Bad Coding – Yaw run away during an icing event. Yaw run away is not something expected during icing. You are more likely to see cable twist if the wind direction sensor freezes up.

- Bad Coding – Clogged gearbox oil filter during high turbulence. Filters are clogged by debris coming from the gearbox not high turbulence.
- Bad Coding – High generator bearing temperature during lightning storm. Generator bearing temp increase probably due to bearing, grease or sensor failure. Not the lightning storm.

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Identifying OMC

Appendix C – System-Component Codes

System	Component
External	General (OMC)
	Catastrophe (OMC)
	Economic (OMC)
	External Communication (OMC)
	Legal, Contractual or Environmental (OMC)
	Off-Taker Transmission & Distribution (OMC)
	Weather – Ice (OMC)
	Weather – Lightning (OMC)
	Weather – Temperature (OMC)
	Weather – Turbulence (OMC)
	Security (OMC)
	Execution Delays (OMC)

Use the External Component descriptions to identify potential OMC causes.

The list of External components listed in Appendix C will help identify legitimate OMC causes.

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Weather - Ice

Ice collects on blades during freezing rain, fog near freezing or as a form of frost. It changes the shape of the airfoil and the balance of the rotor. Ice can form as high as 35-36°F. As air flows over the top of the blade the pressure drops and the temperature also decreases. In foggy conditions near freezing a substantial amount of ice can build up. In some conditions over 1000 lbs. of ice can accumulate causing a real safety risk.

How would you justify coding the following as an Forced > OMC > Ice Event

1. During an icing event a large number of turbines had cable twist faults

   Answer: Frozen non-heated wind vanes

2. During an icing event several towers have vibration faults

   Answer: Could be rotor imbalance or change in a resonance frequency

3. Gearbox oil pump fails during an icing event

   Answer: Not part of an icing event. No clear linkage

Other examples:

- Pitch motor failure – Increased load of Ice
- Power reference faults – Change in airfoil – changes power curve

- Ice is a real safety concern. A chunk of ice falling 300 feet will impact the ground at over 60mph. This can severely damage a truck and easily go through a windshield. Damage has also occurred to overhead lines and pad mount transformers. When ice breaks off of a rotating blade it can travel several hundred feet. Even when all the ice has melted off of the blades the operator needs to be aware that ice could slide off of the top of the nacelle.

Weather – Ice - Restart

Icing events end when any of the following conditions are met:

1. When the Ice melts or falls off and the turbines are safely be restarted
2. If a reset is required:
   - Remote reset if that does not work
   - Local reset
   - Local breaker reset
   - Time to get to the turbine and delays are part of the outage
3. If there is direct damage to the turbine because of ice (ice hitting blade, transformer or nacelle) that is part of the outage
4. Damage from large hail would be handled in a similar manner
5. Individual turbines may have different restart and outage periods
6. Damage other than from the ice would become a new FO event

- Restart for OMC weather events all follow the same pattern and has many branches depending on how each event plays out.
- Generally speaking the event ends when the OMC weather issue is no longer present. There is special consideration for various restart issues.
- When the OMC weather issue is resolved restart begins on an individual turbine basis and may have several steps:
  - The first step is a remote reset from SCADA. If the turbine restarts that ends the outage event for that turbine
  - If the remote reset fails a local reset at the turbine maybe attempted. Time to get to the turbine and any delays are part of the outage
  - If the local reset fails, a turbine main breaker maybe attempted if tripped
  - At this point if there is no physical damage caused by the ice such as blade, transformer, nacelle, anemometer or nacelle damage, and the turbine needs additional repairs the OMC event ends and a new FO begins for the repair
  - If there is ice damage the OMC event continues until the ice repairs are completed.

Weather - Turbulence

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High turbulence can occur at anytime at a wind site. High winds in mountainous areas tend to be the most turbulent followed by the leading edges of mesas, column winds and micro burst. Turbulent winds change direct and speed often and abruptly. Sometimes the wind is so strong that it can push the nacelle or impact the pitch systems ability to keep up with the wind dynamics.

How would you justify coding the following as an Forced > OMC > Turbulence

1. During a nasty winter night with winds gusting above 30 m/s a large number of yaw run away faults occurred
   Answer: The nacelle was pushed in a direction the WTG did not want to go because of high side loads
2. During a micro burst a large number of turbines experienced generator overspeed faults
   Answer: Turbulent wind stresses the pitch system allowing situations where there is an overspeed condition before the pitching can react

Other examples:

- Column winds are when the wind is blowing down the turbine rows instead of perpendicular to the turbine rows. The first turbine in the row creates turbulence for the next turbine and it compounds as each turbine is passed

Weather – Temperature

Wind Turbines are designed to operate in specified temperature ranges depending on the equipment installed. Very cold temperatures impact lubrication and the ability of electronics to function correctly. Very hot temperatures decrease lubricants effectiveness increasing wear of equipment.

How would you justify coding the following as an Forced > OMC > Temperature

1. During the Polar Vortex when temps dropped below -40C the plant experienced are large number of converter IGBT faults
   Answer: Winterized turbines usually have a minimum temperature limit of -30C. IGBT's are very sensitive to low temperatures. In this case the cabinet heaters could not maintain the minimum operating temperature
2. The turbines at plant A have a high ambient temperature limit of 55C Temperatures were running around 50C when a bunch of turbines shut down for over cabinet temperature
   Answer: In this case it was not OMC. A large number of cabinet fans and temperature sensors that control the fans had failed

Other examples:

- Heaters disconnected during the summer caused cold related outages
- Summer and winter prep.

Weather – Lightning

Lightning can impact wind turbines both directly (Strike) and through the transmission system. Blades take the brunt of the direct strikes. Most blades today have adequate lightning protection but there are limits to the voltage that can be handled. Often a blade will whistle if a hole has been bunched in the blade.

Lightning strikes on the transmission can cause brown outs, momentaries to tripped circuit breakers and the lightning may occur many miles away.

How would you justify coding the following as an Forced > OMC > Lightning

1. The techs arrive at plant A in the morning and find 20 plus turbines down for multiple low voltage faults and a few low voltage ride through failures. There was no lightning at the site but there was in the neighboring county. Answer: The faults were probably caused by brown outs and momentaries.
2. A blade was hit by lightning suffered severe damage. The lightning service indicated it was a low voltage event.
   Answer: Lightning protection should have been able to handle this strike. Investigation found the protection had not been maintained.

Other examples:

- Direct strike – failure of the protection or excessive energy
- There are lightning monitoring providers that can ID the GPS coordinates and magnitude of individual strikes

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Failed Protection

Wind turbines often are equipped with protection for various weather conditions. Examples:

- Blade lightning protection
- Blade deicing equipment
- Heated anemometer and wind vanes
- Control box heaters and fans
- Gearbox heaters
- Additional ventilation
- Blade tip over speed protection

When a weather outage occurs a couple of questions need to be asked:

1. Was there protection
2. Did the protection function as designed (if no FO)
3. Was the protection design limits exceeded (OMC)

- There are many protective devices built into most modern wind turbines. Additional adverse weather packages can be install to allow the turbine to operate in a severe weather conditions.
- When classifying downtime it is important to determine if there was a failure of protection (non-OMC FO) or a true weather event (OMC FO)
- Cabinet heaters and fans are often causes for cold or hot weather outages. Cabinet fans have a high failure rate that shows up in the summer as a high temperature issue. Heater thermostats fail preventing the heater from coming on in winter or turning off in the summer. A common work around is to unplug the heater for a repair at a later date.
- Was there protection, did it function as designed and were the protection design limits exceeded should always be considered.

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Failed Protection

Challenge questions – Failed Protection

1. Non-heated anemometer freeze up at a south Texas wind site. FO or OMC
   Answer: OMC – no expectation that it could overcome freezing.

2. Blades ice up with de-icing equipment. FO or OMC
   Answer: FO – protection failed

3. Controller trips off due to cold cabinet temperature. Temperature is not below the turbine design temperature. Heater present. FO or OMC
   Answer: FO – Heater failed , unplugged or turned off

4. Very hot day and controller trips off for high cabinet temperature. Fans not working and heater hot. FO or OMC
   Answer: FO – Heater failed and fans failed to function correctly.

- Protection cost money and in some cases it doesn't make sense to install.
- Weather varies widely across the USA. Protection should be installed where it makes sense and has a positive impact to the bottom line.
- Blade de-icing can come in many forms form electrical heat strips, inflatable cuffs, chemical and generator exhaust pumped into hollow blades. This type of protection is not common.

Transmission Outage

Transmission system outages are generally defined as events on the high side of the substation transformer and classified as OMC. It is beyond the plant boundary in most cases. Transmission outages can be caused by lightning, line slaps, pole failure, car hits pole, birds, debris in the lines, equipment failures and etc. Often the cause is not known. Most of the time these are FO but there can be PO and MO events. Recovery from events can be challenging at times. The outage ends for a turbine when:

1. The turbine automatically restarts when power restored
2. The turbine is reset remotely
3. A local reset or breaker reset at the turbine
4. If the turbine requires repairs, the transmission outage ends and an FO event begins

Snow, rain, ice, mud, road closures etc. does not stop the clock, just delays the process.

Internal Distribution

- The low side of the substation is considered the Internal Electrical Distribution to the turbines or Balance of Plant. It is part of the plants responsibility. Outages may be OMC or FO depending on the situation. One must consider the protections in place and did they work or were they functional. Example – lightning arrestors.

- Restarting from a Balance of Plant outage is the same as a transmission outage.

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Transmission Challenge

The Off-Taker takes a multi day storm outage to make system repairs. During this time the wind site decides to take advantage of the downtime and replace a leaking pad mount transformer. The Off-Taker completes their work early and restores electrical power to the site before the site completes their repairs.

1. Who was in control of the storm outage?
   Answer: The Off-Taker
2. What type of outage would the site characterize the Off-Taker outage?
   Answer: Forced > OMC
3. Could the site extend the Off-Taker outage to complete their work?
   Answer: No – Not the sites outage. The site was taking advantage of the Off-Taker outage
4. How should the site code their extended time?
   Answer: The work was not critical and could have waited, therefore it is a Maintenance Outage

- Whoever controls an outage controls when it begins and ends.
- Other parallel work can take place during an outage but the parallel work cannot extend the original scope of work.
- If the parallel work takes longer than expected and the original work is completed, the parallel work starts its own outage.
- Maintenance Outages should have a specific scope and period for the work to be completed. Don’t pile on additional work as new items are discovered.

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Overlapping Events

- Overlapping events occur often at wind plants. They may extend downtime preventing return to service. The tendency is to want to switch from event to event to optimize the performance indicators. For wind the first in first out rule applies. In other words fix the first problem then you can switch to the next outage. Example:
- An Off-Taker was planning major upgrades to the transmission system leading to the plant. The plant would be without power for 2 months. When the outage began there were 10 turbines down for various reasons (FO) but they needed power to fix. These 10 turbines need to be fixed before they can be switched to the Off-Takers PO > OMC outage. The plant solved the problem by renting generators allowing the completion of repairs
- There is one exception to the switching of outage types. It an OMC code called Execution Delays which has some very specific rules for its use

- Occasionally multiple events occur at the same time. In Appendix D, near the end, is a section that defines Priority of Reporting.
- Remember the first in first out rule before switching outages
- The only way to get around the first in first out rule is to retire the unit.

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Replacement

- Sometimes wear and tear or nature takes out a turbine. Maybe a lightning strike on a blade caused the whole nacelle to burn up. At that point the turbine could be retired or after 60 days of FO placed into Mothball status if waiting to decide to repair. If the decision to repair has been made there maybe opportunity to use Execution Delay (OMC)
- If the turbine is repaired and returned to service there is no change to the Sub-group. Replacement with an identical turbine is considered a repair
- Most of the time replacement occur many years later and the original model is no longer available. In this case the turbine could be replaced with a newer model. Maybe the newer model is larger and takes the place of several of the older turbines. In this case retired turbines hours would be counted until the end of the month and then the turbine count reduced in the Sub-group file. The new turbine would become its own sub-group

- When major events occur that cause major / catastrophic issues, time will be required to decide what to do. If this decision period last more than 60 days, switch to Inactive > Mothball.
- If the decision to repair / replace the turbine is made, Mothball ends. If 60 days of FO has already occurred, Execution Delay (OMC) could be used.
- Replacement with the same make, model and capacity has no impact on the Sub-group.
- If the replacement is different than the old Sub-group gets adjusted and a new Sub-group for the new turbine.

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Refurbishment

- Refurbishment is the Planned replacement or rebuild of most of a turbines systems to bring the unit back into its original operating condition.
- During this process blades maybe re-coated, rebuilt gearbox installed, generator bearings replaced and main bearings replaced. Sometimes small improvements are implemented like updated software, new heated anemometer and wind vane or other improvements
- In this process there is no fundamental change to the wind turbine. The make, model, capacity, rotor diameter and other major components remain the same. Therefore there is no change to the Sub-group configuration

- Although there is no change to the Sub-group configuration, the utility may want to track which Sub-groups have been refurbished. This can be accomplished by making a slight adjustment to the Sub-group name. Maybe adding an “R” sum where in the title.

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Repower

Many plants across the US are in the process of repowering. How Sub-groups are handled during this time can be challenging. There are a couple of paths that may ease the pain.

1. Retire the turbines as they come off line or a major component fails. This removes them immediately from active status. You will need to track the retired hours. At the end of the month or end of the project the turbine counts are trued up. If there are no turbines left in the sub-group it is retired
2. The repowered turbines need to start reporting the first full month after COD if the plant is >=75MW. Usually, COD is when the Off-Taker accepts that the plant is capable of generating its design power. A new Sub-group is created

- Generally, "Repower" is a technical term used when 80% of the turbine is upgraded for tax credits.
- Since 80% of the turbine is changed, this usually requires a new Sub-group
- There are many methods to account for Sub-group changes but the simplest method is to:
  - In the original Sub-group, track all the retired hours until the end of the month that all the turbines in the Sub-group are retired. Then retire the Sub-group
  - If all the turbines in the Sub-group are not to be retired, track all the retired hours until the end of the month that turbines are retired. Then adjust the Sub-group turbine count for the remaining turbines.
  - For the Repowered turbines, create a new Sub-group and start tracking the first full month after COD.

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Environmental

Environmental events come in several flavors birds, bats and eagles leading the pack. Also to be considered are noise and flicker (passing of blades past the sun). These are all OMC events.

- Bird Migration – One area has had a 3 month no generation during the summer
- Condors and large eagles may have shut down rules when they encroach on the plant
- Bats may require shutdown during specified periods when they are migrating
- Bats may also have shutdown requirements at specified wind speeds when they tend to be out hunting

These pose the same issues as transmission outages following the first in first out rules.

- Noise and Flicker could also be categorized as Legal / Contractual (OMC) depending on the circumstances. A county may have noise ordinance for noise or flicker. These should be classified as environmental. Other times the noise or flicker may be a contractual agreement defined in the land lease for the turbine. These should be classified as Legal / Contractual (OMC)

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