

MANAGING HUMIDITY IN OFFSHORE WIND TURBINES

COTES

Dry air makers

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**MANAGING
HUMIDITY**
IN OFFSHORE
WIND TURBINES



CONTENTS

07 TOUGH CHALLENGES

08 HUMIDITY - THE INVISIBLE ELEMENT

11 COMBATTING CORROSION

16 THE CONDENSATION QUESTION

18 ELIMINATING ELECTRICAL GLITCHES

20 BIOLOGICAL BURDENS

22 DOWNTIME COSTS MONEY

24 CONDITIONS EN ROUTE

29 BETTER THAN THE REST

32 TRUTH ISN'T BLACK AND WHITE

34 COTES RECOMMENDS

TOUGH CHALLENGES

Tough stuff

Offshore wind turbines have to cope with some of the harshest operating conditions on the planet.

They are constantly exposed to air full of particularly aggressive combinations of moisture and corrosive chemical salts – for decades.

Location, location

Offshore wind turbines always involve major expenditure. Their location adds big zeros to infrastructure and installation costs, as well as to service and maintenance bills should anything go wonky.

This means any downtime makes big dents in balance sheets, payback projections and the return-on-investment calculations that are pivotal for project viability.

And that's why they are an investment well worth protecting.

VALUABLE INSTALLATIONS WORTH PROTECTING

Offshore wind turbines are constantly exposed to air full of nasty combinations of moisture and corrosive chemical salts.

They're an investment well worth protecting.

HUMIDITY

THE INVISIBLE ELEMENT

Prime determinant

One of the most important factors affecting durability, reliability and uptime in offshore wind turbines is the levels of moisture in the air – the relative humidity. Humidity is a prime determinant of whether or not corrosion takes place on surfaces and equipment. It also determines the rates at which such corrosion processes develop.

Humidity can also directly affect electronics, electrical installations and control systems. This often means it plays a key role wind turbine glitches, and the expensive downtime that results. The levels of moisture in the air also impact many other important operating parameters – and that's why dealing with this invisible element effectively can work wonders with your costs.

Controlling what's happening

You can't see humidity, and it's often overlooked. Managing the humidity in the air is the most cost-effective way to tackle many of the practical issues and operating glitches in offshore wind turbine installations.

Modern humidity management is a well-documented, tried-and-tested technology whose cost-effectiveness leaves traditional approaches like heating, ventilation and coatings in the dust.

Prevention – always better than cure

The basic point is that it's much quicker, easier and cheaper to prevent a problem from arising than to have to deal with it once it has begun to impact your operations.

But focusing on humidity issues isn't too well known in the world of offshore installations – yet. This is a fact that the Danish company Cotes wants to change – hence this booklet.



COMBATTING CORROSION

A force of nature

Corrosion is the decay, damage or destruction of a material resulting from its surrounding environment. It's a natural process, and in aggressive offshore environments it's pretty much impossible to completely prevent the onset of corrosion.

Corrosion progresses inexorably, gradually causing more and more damage and material degradation – unless concrete measures are taken.



PROBLEM

PLETHORA OF PARAMETERS

Lots of different parameters are involved in determining whether corrosion takes place in the nacelles, and towers of offshore wind turbines – and how fast it develops. The normal culprits include:



Humidity

Humidity is one of the prime determinants of atmospheric corrosion in offshore wind turbines. In the marine environment, there is always lots of moisture in the air. This means all the surfaces – inside and out – are constantly exposed to an aggressive chemical soup – different combinations of chemicals interact with the moisture in different ways. If the relative humidity increases to approx. 60% or more, corrosion takes off in a big way. As humidity increases past this point, corrosion rates increase exponentially.



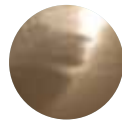
Salt

The salt content of air above the sea stems from very fine droplets and spray from whitecaps and breaking waves. The salts present in marine environments are normally in aerosol, spray or crystal form. Different combinations of different salts have widely varying effects on corrosion specifics – especially when they come into contact with any moisture in the air.



Dust and particles

When dust particles collect on metal surfaces, they often absorb either moisture or weak sulphuric acid from the air. The dust traps the water or acidic solution right against the surface of the metal, making corrosive attack much more likely. Dust particles can also contain a wide range of contaminants that break down the protective films on metal surfaces, supporting corrosive processes.



Temperature

The surface temperature of structures and components also influences corrosion by influencing the relative humidity, the dew point, the duration of wetness and the kinetics of the corrosion process. Corrosion rates normally double for each 10°C increase in ambient temperature.

SOLUTION

PREVENTING RATHER THAN TACKLING

Controlling conditions

There are two requisites for corrosion taking place – both oxygen and water must be present.

It's pretty much impossible to get rid of oxygen. But you can do something about water. By far the most cost-effective way to reduce, limit and control the many corrosion processes encountered in offshore wind turbines is to regulate the levels of moisture present in the air.

With a relative humidity of about 40% or less, corrosion problems simply don't have the preconditions needed to get started – regardless of the particular set of chemical conditions.

Conditions determine specifications

By removing excess moisture from the environment inside the nacelle or tower, you make it possible to prevent the cathodic reactions at the heart of corrosion processes.

Adsorption dehumidification technology enables you to establish – and maintain – the exact levels of humidity necessary to balance the surrounding conditions – and thereby avoid rust, corrosion and other material degradation issues.

The exact figure depends heavily on the particular combinations of salts, as well as any pollutants or contaminants that may be present in the air at each particular location.

MORE WITH LESS

Adsorption dehumidification technology involves small boxes that have lots of practical advantages.

- > The units are relatively small and light in weight
- > They can be mounted virtually anywhere within a nacelle or tower
- > They use hardly any energy
- > There are hardly any electronics
- > They are built using standard, off-the-shelf components of top quality
- > They are exceptionally reliable
- > They only need servicing at intervals of 1–2 years

THE CONDENSATION QUESTION



Relative temperatures – nasty effects

Another big problem for the structures and systems in offshore wind turbines is condensation.

Condensation is the result of the fact that the air, which inevitably contains a certain level of moisture, has a different temperature from the surfaces with which it comes into contact. If a surface is colder than the dew point of the air, some of the moisture present undergoes a phase change and forms on the cold object as water.

Seasonal changes, different weather conditions and lots of other variables mean the air temperature inside an offshore wind turbine is constantly fluctuating.

This means moisture-laden air in contact with cold surfaces often reaches its dew point. Condensation then forms, with the danger that this moisture then gathers on components, equipment and structures.

Wetness unwelcome

The resulting drips and puddles – often made corrosive by the salts and other contaminants present in the air in any marine environment – give rise to lots of decidedly unwelcome problems. These range from structural corrosion and the degradation of components, to short circuiting and the malfunctioning of valuable and sensitive equipment essential for uninterrupted, glitch-free operation.

CURBING CONDENSATION

Prevention better than cure

By controlling the levels of humidity in the air inside offshore wind turbines, adsorption dehumidifiers make sure condensation simply cannot form on any of the surfaces.

This is done by making absolutely sure the dew point in the air is constant and under full control, and always matches the temperature of the surfaces the air comes into contact with.

Under such conditions, it's simply impossible for condensation to form.

ELIMINATING ELECTRICAL GLITCHES

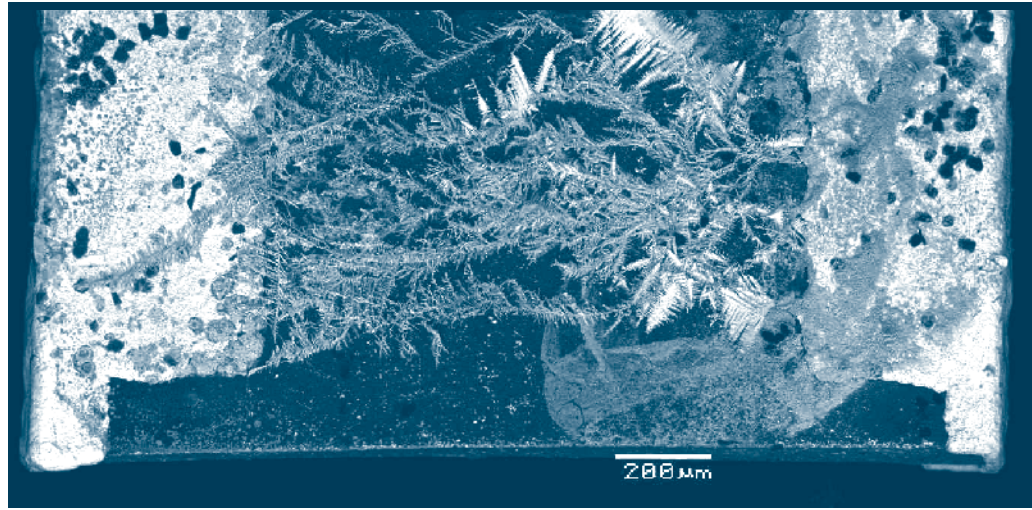


FOTO: CENTRE FOR ELECTRONIC CORROSION (CELECORR), DTU, DENMARK

Sensitive stuff

Humidity often has big effects on the efficiency and reliability of electrical and electronic installations in offshore wind turbines. Moisture and electrical currents never make a good combination.

Excessive, uncontrolled levels of humidity can give rise to

- > corrosion in components and soldered connections
- > short-circuits
- > flashovers and current leakages
- > electrochemical migration

that result in both here-and-now operating glitches and long-term deterioration of key installations.

Avoiding unpleasant surprises

Excess moisture in the air inside wind turbines can result in all kinds of distinctly undesirable glitches and short-circuits in key parts such as printed circuit boards, power switches, generators and power converters.

This makes it particularly important to remove moisture from the air surrounding sensitive systems and electronics that are critical for uninterrupted operation.

Avoiding humidity is also crucial in order to prevent the contact surfaces of switches corroding. And to guard against electrical short circuits. To avoid electrochemical migration, it's also important to make sure the surfaces of circuit boards and other critical components are dry before the electronics are switched on.

DRYNESS NEXT TO GODLINESS

Guarding against glitches

Keeping the surroundings – and particularly the air – dry helps you prevent operating irregularities in a wide range of electrical and electronic systems – as well as preventing their long-term deterioration.

This can be done most effectively and inexpensively with adsorption dehumidifier equipment. Which has the added advantage of taking up very little space, weighing very little and using only a minimum of energy.

Less complicated, less costly

Reliable, consistent control of the levels of humidity present in different sections of an offshore wind turbine therefore paves the way to substantial savings on electrical and electronic systems, because it's possible to use equipment that features less advanced and less costly specifications.

If you make use of modern humidity management to prevent problems from arising, this can also pave the way to substantial savings on other specifications – for surface coatings, electrical design and protection, etc.

BIOLOGICAL BURDENS



Microbes multiply

There is a significant risk of biofilms and microbial growths such as mould and mildew if levels of relative humidity are high. Such biological contaminants are renowned for thriving in humid environments, or in places plagued by the effects of condensation.

Such growths are never good for air conditions, equipment reliability or long-term structural integrity. And that's not good for profitability.

Cultivating corrosion

Particular types of biofilms and microbial organisms give rise to corrosion. Biofilms can create aggressive organic acids, while microbes and/or bacteria form corrosion cells or metabolic by-products that give rise to anodic/cathodic reactions, or that support such reactions. Organisms also often have hygroscopic properties that have corrosive effects similar to salts and other chemicals.

The microbes that cause such corrosion are normally bacteria or mould fungi. Examples include iron-oxidising and sulphate-reducing bacteria types that cause corrosion on steel. Aluminium alloys can also be affected in the same way.

FENDING OFF FUNGALS

Making surroundings inhospitable

The most effective countermeasures against micro-biologically influenced corrosion involve making the environment inside the wind turbine inhospitable – or even completely inhabitable – for such microbes and fungal growths, and biofilms of all types.

Growth prevention

The most cost-effective way you can do this is by ensuring low humidity and good air circulation. Installing appropriate adsorption dehumidification equipment enables you to lower the humidity in the air, and keep it constant regardless of outside conditions.

And when humidity is sufficiently low, fungal growths simply cannot occur. As always, prevention is better – and cheaper – than much cure.

PROBLEM

DOWNTIME COSTS MONEY



Standstill sequences

When an offshore wind turbine has been stationary for a while – for whatever reason – accumulations of moisture and the humidity in the air inside the structure can give rise to lots of troublesome practical issues.

That's why some companies opt for different kinds of heating solutions to warm up the turbine in the attempt to avoid issues stemming from humidity in the air. The difficulty is that introducing heavy, bulky heating equipment adds to costs all done the line – not least when it has to be run.

Delays are expensive

In addition to requiring the use of costly energy – and not being particularly effective – warming up procedures of this kind typically take as much as 2–4 hours. The turbine produces no electricity throughout this entire time – and therefore generates no earnings.

Which doesn't help performance figures or your balance sheets.

SOLUTION

GLITCH-FREE STARTS

Full control while stopped

Installing modern adsorption dehumidification systems enables you to keep levels of humidity under full control while the wind turbine is stationary – for whatever reason. And to do so easily and inexpensively.

Special controller units automatically turn the dehumidifier on and off in order to maintain any designated relative humidity set point, as required to meet local conditions. Mechanical hygrometers are also available.

This means the energy costs of running such a dehumidification system are negligible – it simply turns itself on when needed. And turns itself off again as soon as humidity conditions are back on spec.

Rapid commissioning and restarts

If adsorption dehumidification systems were included in the wind turbine specifications, the air conditions inside the nacelle and tower are ideal as soon as erection is complete. This eliminates many of the practical difficulties often associated with starting up and commissioning new turbines and wind farms, and greatly reduces the risk to costly nacelle systems and components.

And if you can keep conditions inside the nacelle and tower constant and under full control for however long a wind turbine may be stationary – during breakdowns, repairs and service – you can bring each wind turbine back on line and back to earning revenue as quickly as possible.

CONDITIONS EN ROUTE



Long supply chain

The nacelles and towers of offshore wind turbines are often a long time in transit from factory to erection site.

In their long journey from one to the other, it's inevitable that they're rarely under ideal conditions.

They can be exposed to fluctuating weather and climate conditions the whole time.

Long time no protect

A long time can pass between each turbine being finished and shipped off, and it being installed and then finally brought on line. During all this time, the nacelles and towers are exposed to a variety of climate conditions as they are moved from one part of the world to another.

They'll probably also be exposed to weather of many different kinds, and when they move out to sea they'll be surrounded by air containing a nasty soup of aggressive contaminants.

None of this is a good start for any high-value investment.

KEEP ON TRUCKING

One installation the whole way

Adsorption dehumidifiers provide the big advantage of unobtrusively doing their job the whole time the nacelle and tower is *en route*, whether being transported or stored. They use only very small amounts of energy, and don't require any complex ancillaries. Sensors automatically turn the dehumidifiers on for a short time if the relative humidity approaches any pre-designated set point.

You can then leave the same equipment in place and in service – keeping air conditions dry and under control – while the wind turbine is being erected and brought into service. You benefit from the same reliable degree of protection, regardless of project hiccups and how long completion and commissioning may take.

Prevention better than cure

Offshore wind turbines are a big investment that it pays to protect. If they are exposed to conditions that have negative effects while in transit and while in places like open storage areas, docksides and ships' decks, they may never recover from such a bad start to their service lives.

By contrast, if you make sure adsorption dehumidifiers are installed inside to keep humidity conditions constant, your nacelles and towers can arrive at the erection site in best possible condition. This paves the way to easier, glitch-free commissioning as well as a significantly longer service life.

BIG PAYOFFS FROM A LITTLE BOX

The levels of humidity inside the nacelles and towers of offshore wind turbines – and in some wind farms the base sections, too – can be controlled effectively using modern adsorption dehumidification technology.

Adsorption dehumidification only requires a relatively small investment. And it provides big benefits.

- > It dramatically extends the service lives of the entire wind turbine and all its mission-critical sub-systems
- > It significantly reduces service and maintenance costs throughout the service life of the installation
- > It cuts down on expensive unscheduled downtime that slices into revenue
- > It is 10–20 times more energy-efficient than any possible alternative set-ups or technologies, resulting in payback times of less than 12 months, based on energy savings alone.



BETTER THAN THE REST

Many of the traditional approaches to dealing with excess humidity in offshore wind turbines are actually counterproductive. These include heating, ventilation and surface coatings.

Heating is costly

Some manufacturers, for example, install large hot air generators in the nacelle of the turbine. These use lots of expensive energy, making them heavy on operating costs.

Despite traditional thinking and layman 'common sense', heating the air in the nacelle or tower can never be a solution to humidity problems. It may be useful – yet expensive – for helping keep lubricants above their required operating temperatures. But when heated, the air still has the same moisture content in terms of g/kg – it is only the relative humidity that has been reduced.

Ventilation is futile

Contrary to much popular belief, ventilation is also completely ineffective in efforts to maintain control of humidity in offshore wind turbine nacelles.

This is because any air entering the nacelle normally has pretty much the same levels of humidity as the air already inside. Often it will be worse, because of the effects of sea spray and water droplets laden with aggressive salts. This means any incoming ventilation air will actually increase the problems associated with combating the corrosive effects of salt inside the nacelle.

Surface coatings are superfluous

One of the most traditional ways to try to counteract or prevent many of the undesirable effects of high levels of humidity is to cover as many surfaces as possible with coatings. These are usually intended to prevent moisture, condensation and corrosion from actually reaching through to the surfaces underneath.

Such coatings are expensive, and add weight – and weight means more costs right down the supply chain. Coatings don't solve the problem of dealing with humidity – they just try to ward off its effects. The laws of physics dictate that it's a battle unlikely to be won.

TRUTH ISN'T BLACK AND WHITE

Forget cookie-cutter solutions

Erecting, operating and servicing offshore wind farms can never be by-the-numbers routine. Conditions vary enormously, as do the challenges you have to face in overcoming them.

Experts from many different disciplines and different suppliers have to work together to find the best solution for each particular site, each erection programme and each different equipment set-up. There are no standard, cookie-cutter solutions.

Conditions determine conclusions

Research about air and humidity conditions inside wind turbines installed in marine environments is ongoing, and the technical community's know-how about this specialist field is still evolving by leaps and bounds.

Lots of different parameters and conditions need to be taken into consideration, and balanced against each other. The world's experts are still discussing the relative influence of many of the parameters that affect corrosion in offshore wind turbines.

The complexities of the 'chemical soup' in the air mean there are no black-and-white answers about what's best.

One thing's for sure

But the one thing that is sure is that effective humidity management is by far the easiest and most cost-effective way to deal with the majority of mission-critical problems encountered in wind turbines installed offshore.

Cotes has supplied thousands of adsorption dehumidifiers to many of the major manufacturers of offshore wind turbines throughout the world.

Based on the practical, long-term experience we've harvested from this, Cotes normally recommends keeping relative humidity under 50% – but each case is different.

Talk to us about the conditions in your installation – and we'll find the best answer together.

A question of standards

There are no hard-and-fast guidelines about the most relevant standards and specifications for air conditions inside wind turbines installed in marine environments.

Some experts consider marine standards such as NORSOK M-501 and ISO 20340/ISO 12944 regarding coatings as good guidelines. Other experts look to the ISO 9223 Corrosivity Classification.

This is a field under development, and there are as yet no definitive conclusions.

COTES RECOMMENDS

Tougher than most

The dehumidification systems needed for wind turbines have to tackle more challenging requirements than the systems used to manage levels of humidity in installations on the ground.

And wind turbines installed offshore have to be able to withstand operating conditions substantially more aggressive than their onshore counterparts.

Cotes recommends avoiding ...

This is why Cotes recommends avoiding all kinds of traditional dehumidifiers and adsorption dehumidifier solutions designed for land-based use.

- > Traditional dehumidifiers only provide a small flow of regeneration air.
- > The filters are therefore usually too small to be suitable for use in offshore wind turbines.
- > The filters and related equipment are not designed to deal with moisture-laden air with a high salt content, and don't have sufficient capacity.
- > Traditional dehumidifiers aren't built to cope with long periods between filter changes and service inspections.
- > They often contain lots of electronics, which have a tendency to break down.

Cotes recommends using ...

Cotes supplies a comprehensive range of adsorption dehumidifier solutions that are specially designed for use in offshore wind turbines. These solutions are backed by solid long-term experience from installations in thousands of wind turbines throughout the world.

Using Cotes adsorption dehumidification systems that are specially designed, built and configured for installation offshore gives you big improvements to performance, profitability and return on investment.

- > The best possible humidity management in nacelles, tower and base sections.
- > The advantage of using the same dehumidifier unit during storage and transport of the nacelle/tower, and when the wind turbine is erected and brought into service.
- > Exception reliability while in service, along with very low running costs.
- > Exceptionally long service intervals for the dehumidifier systems, matching normal service intervals for the wind turbine itself (>12 months).
- > Exceptionally long service life for the dehumidifier and any ancillary systems.

COTES EXPERTS CAN HELP YOU DECIDE

There are many factors to take into consideration when planning, configuring and installing dehumidification equipment in offshore wind turbines. Geography and climate – structure, equipment and materials – operating conditions and performance requirements – all these play a role.

That's why it can be a good idea to involve Cotes experts early on in the decision-making process, so you can benefit from our unique humidity management experience and expertise in full.

