Automatic Weather Station Design for demanding environments

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Importance of accurate weather information from the arctic regions has increased due to the major effect of the global warming in the polar region. The density of AWS network in arctic regions is scarce and when infrastructure is not available, new installations are much more challenging and expensive. The maintenance of the network can be costly as well. The installation and maintenance costs can be reduced by careful design and also the data quality can be improved. The metadata and status information from stations are important for data validation. The operating environment makes the design of automatic weather station for arctic desert challenging, the AWS shall operate autonomously 24/7 over the years, temperature range can vary between -60 and +35 C, wind speed can be over 30 m/s and ice can be formed to structures. When mains power is available, the sensors and structures can be heated but still the weather station has to survive if the mains cuts of for some time, which is easily happening during severe weather events. When mains power does not exist, the design is even more critical, in polar areas, the solar power is not available at winter time and battery capacity is reduced significantly in low temperature.

Electronics design

Automatic weather station consists of several electrical components. The main unit includes main processing unit, mostly called as data-logger, power supply unit, battery charger, batteries, communication device(s) and wide range of sensors. The low temperature requirement is the most challenging for electrical components. The standard industrial temperature range is only down to -40 C and most of manufacturers specifies the low temperature range only down to -40. It is not possible to get standard electronics components as processors memory chips etc. for lower temperature range than this standard industrial range and specifying the end-product for lower temperature than component is specified is always a risk. To minimize the risk the design or even each units has to be tested in low temperature. Typically the components and units are working still fine in lower temperature than specified but without verification it is not possible to know what happens. If the design fails in the low temperature the important information at minimum temperature is not recorded and important data is lost. In the automatic weather station the components can be from several suppliers. Earlier, all units were made by a single manufacturer, but in that time the units were not available in the market. Typical example of commercial component in the automatic weather station design is mains power supply unit. Several power supply units specified for industrial temperature range are available. When using commercial components the supplier shall be selected to be reliable and capable to provide support over a long time period. The main processor unit shall be designed especially for a wide range of temperature. If the heart of the system fails the whole system fails. For electronics design the power consumption is critical parameter. In the polar areas the system might need to operate over several moths with only batteries.

Mechanical design

The automatic weather station mechanics consists of 10 meter high mast, electronics enclosure, sensors and fasteners. The mechanics shall withstand all environmental conditions. Materials used shall be corrosion resistant and somehow the whole system needs to be verified before installation. Electronics enclosure must be waterproof but it should also have pressure equalization in order to avoid the under pressure inside cabinet. The electronics enclosure should have possibility for thermal insulation and internal heating. In some cases even several levels of insulation and heating can be needed. With thermal insulation the heating can be made with less power but on the other hand the insulated enclosure can cause challenges in high temperature. Insulated enclosure requires extensive testing in environmental chamber to validate the heating power requirement to meet the internal temperature limits with minimal heating but as well to verify the high temperature specification for the design.

Mast structures with all sensors needs to survive in heavy wind conditions and with additional load caused by icing in structures. Wind load calculation is needed to prove the design specification of the mast and installation mechanics. The corrosion resistant materials are important in coastal installations but as well in any location to ensure the long lifetime of the system.

Telemetry

The telemetry options are limited in the arctic region compared to inhabited areas, the satellite communication is the only possible telemetry option in most cases. In the polar areas even the number of available satellite systems are limited. Geostationary satellites as Goes, Meteosat and Inmarsat are not any more available and what is left are some commercial satellite systems such as Iridium and Argos. The satellite communication increases easily the communication costs, pricing is typically based on transmitted data amount. To minimize the data amount the data shall be packed. Based on the cost structure and power consumption of the devices TCP-IP communication is not feasible at all and reasonable communication method is based on short burst packet data where the packet size can be even only 32 bytes. Today the most flexible and cost effective communication would be Iridium SBD. Low cost hardware components are available for iridium SBD communication with wide range of temperature. The Iridium SBD communication is bi-directional and the satellite coverage in polar areas is good enough to provide nearly real-time data transfer.

Sensors

The sensor selection for the Arctic region depends on the power availability, if enough power is available heated sensors can be used. With heated sensors accurate measurements can be performed in all weather conditions. With non-heated sensors the measurement accuracy depends on weather conditions and data can even be missing for some time periods. The heating capability is the main parameter when selecting the wind sensor. Ultrasonic wind sensor is the perfect selection when heating is available but without heating frost or ice in sensor heads can block the measurement totally. Analog wind sensors are more robust and without heating just the data accuracy is effected by low temperature frost and ice and situations without any data are rare. In cup anemometer snow inside cups effects to aerodynamics and cold temperature effects to rotation friction. For installations without heating, light weight plastic mechanical sensor would be the best solution, frost formation is lower than in metallic structure. Pressure sensors are widely specified to operate down to -40 C but it does not mean that sensor stops operation at that temperature. Typically this means the sensor accuracy specification is valid down to -40 C and in lower temperature the sensor is less accurate and the exact accuracy is not specified. Optical sensors should not be used without heating, the snow and frost will block the sensor easily. For precipitation measurement weighting sensor is the only sensor type for measuring all precipitation types. Rim heating in precipitation sensor ensures the correct operation in all weather conditions but even without heating the operation is correct but risk for aperture getting stuck by snow exists.

Software design

In the software design it is most important to validate the measurement data as much as possible in-situ. The software shall have intelligent power management algorithms and capability to adjust measurement and data reporting intervals based on available power. All measurements has to be validated and measurement quality information shall be stored for later analyses. All data including metadata needs to be stored at weather station, the packed based satellite communication does not support post collection and then the only way to get the statistical data collected is to get those from automatic weather station during maintenance visit. The software shall support bi-directional satellite communication with possibility to get metadata and status information from station by request. Measuring and reporting interval needs to be adjustable remotely. Is not possible to update the software by using the packet based satellite connection. The software update has to be straight forward operation during maintenance visit if that is needed.

Powering

The mains power supply is the preferred powering option. With mains the sensors and enclosure can be heated. The main processor unit shall control the heater inside enclosure also a safety thermostat is needed to cut the power from heater when temperature limit is reached. During a start-up the heating should be on to ensure the system start up even in a really low temperature.

When the mains power is not available the power options are solar panels, wind generator and fuel cell. The best option is to have hybrid power system with solar panel and wind generator. The fuel cell is a bit more expensive and not robust enough for low temperature operation. In the polar areas the solar panel generates power only during the summer season and nothing during the winter season. The power system for solar only has to be designed so that batteries are charged during summer time and the battery capacity should be enough for the whole winter season without charging. In the solar power system the panel size is not critical but battery capacity has to be large. The wind generator makes a big difference, it can generate power at any time of the year. Vertical axis wind turbine is the most robust wind turbine to survive in heavy wind conditions but there is also robust units in propeller type of wind turbines.

Batteries for low temperature operation has to be selected carefully. The standard lead acid battery has only a little of the capacity left in temperatures below -20 C. Specific low temperature batteries are available but the price is still high, anyway the battery technology is developing fast and prices are coming down.

Installation

The automatic weather station for demanding environment has to be designed to be installed easily and should not require heavy machinery for civil works but still the structure has to survive in all weather conditions. To protect the electronics against lightning damages the lightning protection and protective grounding has to be made carefully and the manufacturer has to provide proper instructions. Thunder is not so common in the arctic areas but in the most of cases the weather mast is the highest point in the area.

The batteries should be installed on the ground level or even underground if possible to keep the batteries as warm as possible in the winter time. When the battery pack is covered by snow the temperature is much higher than up in the air during the coldest season, the challenge in this installation is to keep the batteries dry during the spring time when show smells off.

Solar panels shall be installed in vertical position to avoid the snow covering the cells.

Maintenance

The maintenance cost is easily the highest cost during the lifecycle of the automatic weather station. When the automatic weather station is installed in wilderness area, far away from the inhabited areas it can take several days and even helicopter transportation to reach the station. One annual maintenance visit should be enough to keep the system in perfect condition. In design phase that should be taken in account. The weather station design has to be standardized and it has to be well documented, all spare parts and replacement parts have to fit into the system without any onsite adjustments. Sensor calibration is not possible on-site and calibrated replacement sensors shall be installed during the maintenance visit. The automatic weather station shall store the sensor information to metadata file. The diagnostics information needs to be available when planning the maintenance visit and shall be possible to get from station remotely.

Conclusion

Weather station for demanding environment shall be standard product. The whole system shall be tested against environmental requirements to verify the real characteristics of the system. In the product development the feedback from installed base is most important for improving the product. When the design is made for single installation the extensive testing is not possible and feedback from installed base is not easy to use. The maintenance of the well designed and fully tested systems is cost efficient and data quality and availability is better.

This document is based on over 30 years experience in AWS design for polar areas and several installations in Antarctic and arctic regions.