Seven Major Causes of Wind Machine Failure White Paper

Background

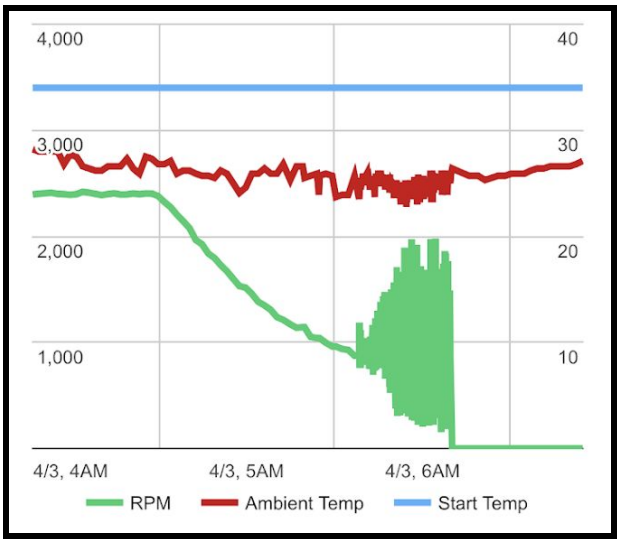
Wind machines are agricultural equipment you see every day; but rarely think about. These machines were developed in the 1960's for active frost protection, and operate by breaking inversion layers and circulating warm air. Wind machines are ubiquitous in citrus and apple farming, typically one fan per 10-15 acres of fruit. We estimate approximately 55,000 units installed in the US, each with a useful life of 20+ years.

There have been few advances with wind machine technology since the introduction of the engine AutoStart in the late 1990's and a tightening of EPA requirements in the early 2000's. The AutoStart starts an engine without human interaction. For wind machines the AutoStart is usually triggered from a temperature probe that acts like a thermostat to turn the engine on and off within a preset temperature range. While an AutoStart provides convenience to the grower, there is no way to insure the machinery is operating properly without physical inspection.

Altrac analyzed data collected from over 500 wind machines and estimates the engines fail to start ~5% of the time due to human error, low battery or fuel, and mechanical issues. Most growers employ ranch personnel to drive around the orchard during frost events to make sure the machines are running. The sections below describe the top seven reasons for wind machine failure, and how to recognize them visually using the Altrac phone application.

1: Runs Out of Fuel - Engine Surge

After several nights of continuous operation, wind machines frequently run out of fuel. When a propane powered wind machine loses pressure due to low fuel level, the machine surges and the RPM varies wildly causing the wind machine to 'buck'. Running out of fuel can damage the wind machine's gearbox, clutch, or other components costing several thousand dollars to fix.

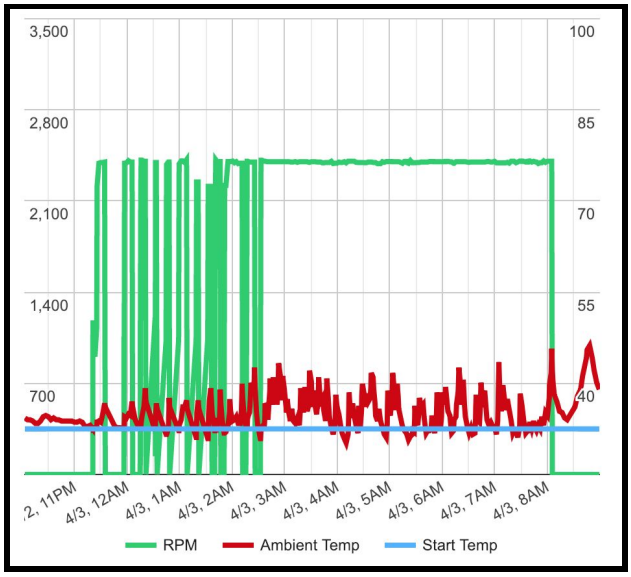


Until the Altrac device provided trend data, it was not common knowledge that the wind machine slowly loses RPM before it begins to surge. The adjacent graph shows a wind machine running out of fuel over 2 hours. Using the Altrac app, if you ever see your wind machine slowly losing RPM, immediately shut down the wind machine to protect your machine from damage.

2: Temperature Probe too Close to Exhaust - Premature Shutdown

If your temperature probe is too close to the exhaust of your wind machine, it will heat up each time the engine starts and prematurely shutdown your wind machine. The rapid heating and cooling will cause your wind machine to cycle on and off frequently. This cycling causes excess wear and tear on your machines.

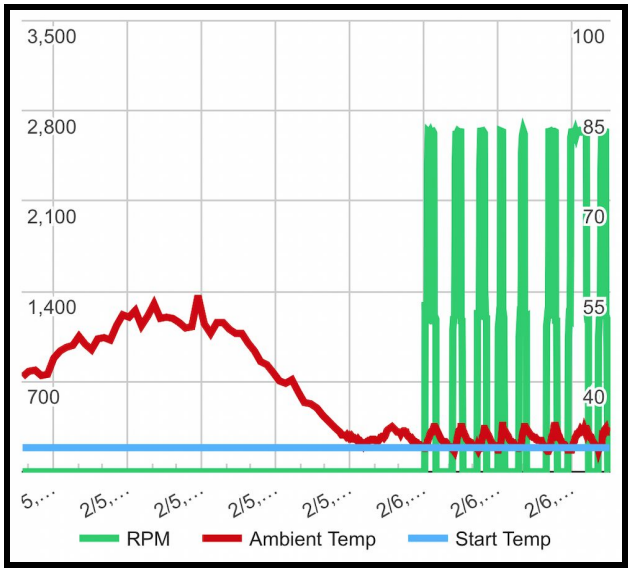
If your wind machine cycles on and off frequently, check to make sure that your temperature probe is at least 40' from the exhaust of the wind machine. Also, be sure to locate the temperature probe on the side opposite the exhaust pipe so that hot air does not blow onto the probe.



3: Strong Inversion Layer - Frequent Start/Stop Cycles

During weather events with strong inversion layers, your wind machine may start and stop much more frequently than a during a weak inversion layer. When the inversion layer is strong, the temperature at ground level increases more quickly and causes your wind machine to cycle on and off more frequently. During some events, the cycling may be excessive. The data looks similar to conditions where the temperature probe is too close to the exhaust. However, the air temperature varies less than if exhaust triggers the machine to stop.

To decrease the number of engine cycles, you can increase the machine stop temperature 1-2 degrees higher. This gives the wind machine a wider window to operate and decreases frequency of starts and stops. This saves you wear and tear on your machine.

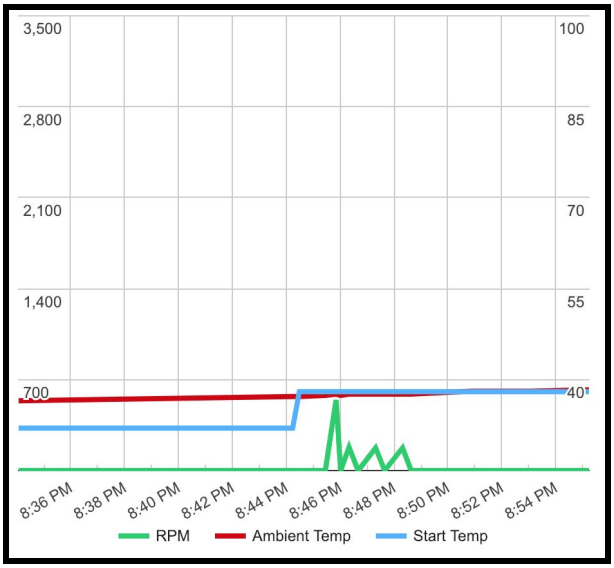


4: Fuel Valve Shut - Failure to Start

If your fuel is turned off and your AutoStart attempts to run your wind machine, you will see several spikes of RPM while the engine tries to start.

The number of attempts to crank over an engine vary among wind machine manufacturers, but are usually between 3-5 times.

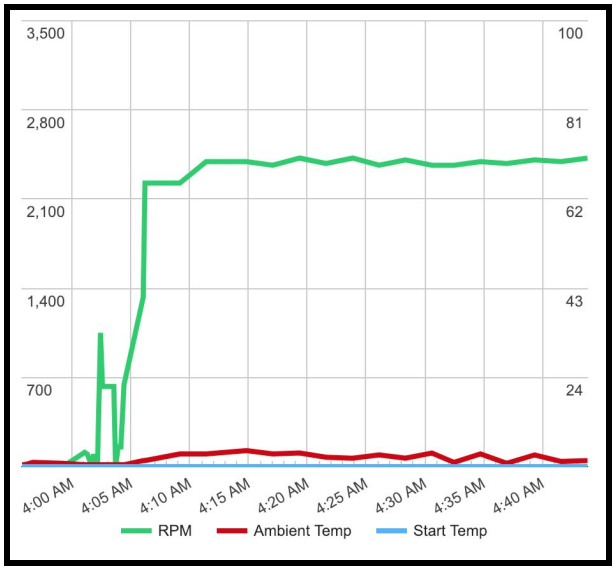
Simply opening the fuel valve will fix this issue.



5: Mechanical Problem - Failure to Start

Wind machines fail to start for many different reasons: low battery, viscous oil, bad starter, blown fuse, etc. In the adjacent chart, this machine tried to crank 3 times in auto mode and failed to start. A ranch manager visited the machine and successfully started it in auto mode.

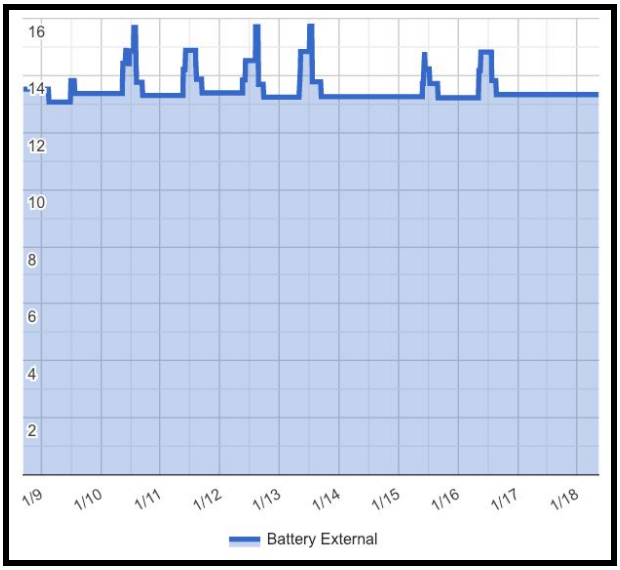
We observe that approximately 5% of wind machines fail to start on any given night. In this case, Altrac notified the ranch manager of the problem immediately and was able to fix the issue within minutes.



6: Solar Panel or Battery Tender Broken - Dead Battery

Most modern wind machines have solar panels wired to the engine's lead acid battery. This solar panel keeps the battery charged which prolongs the battery's life and ensures the battery is ready to operate year around. This graph clearly shows the battery voltage rising during the day and evening out at night.

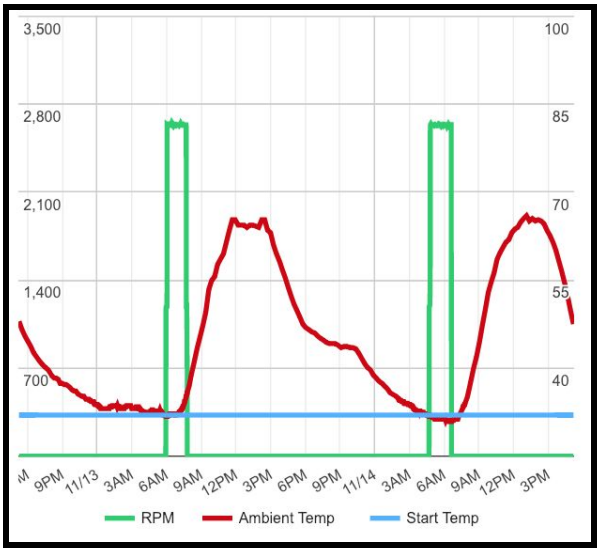
However, if the battery voltage does not rise during the day while the solar panel is attached, it could mean the solar panel is covered or the battery tender is broken. This graph shows several consecutive days where the battery voltage does not rise. It could be due to cloudy or rainy weather, but if it continues, check to make sure the solar panel is outputting the correct voltage.



7: Machine Runs but Temperature Doesn't Change - Fan Blades Not Spinning

The wind machine blades connect to the engine via the drive shaft. Often these drive shafts have shear pins that can break during operation. The pins are meant to protect the engine during fuel outages which cause engine surging and other traumatic events. However, the pins often fail prematurely and the blade of the wind machine stops spinning.

The graph to the right demonstrates the event where your wind machine is running (RPM is normal), but the ambient air temperature is not rising. If you see your wind machine running but the air temperature is not changing at that location, you should check the pin and ensure the blades are spinning



Altrac Wind Machine Control Station (ST-100)

Altrac produces a cost effective solution to enable growers to control their wind machines and other frost protection equipment from a smartphone or laptop. The Wind Machine Control Station (ST-100) started as a practical solution to a vineyard's problem, and has since been perfected over years of rigorous testing.

The Altrac **ST-100** enables farmers to:

- Monitor equipment from multiple ranches
- View real time data from individual machines
- Remotely start / stop multiple machines
- Change temperature start/stop temperature
- Send alerts via text, email, or phone call

The system installs on your existing equipment in about 30 minutes, typically mounted on the tower ladder for improved reception. The **ST-100** works with all wind machine manufacturers, and supports diesel, propane, and electric engines.

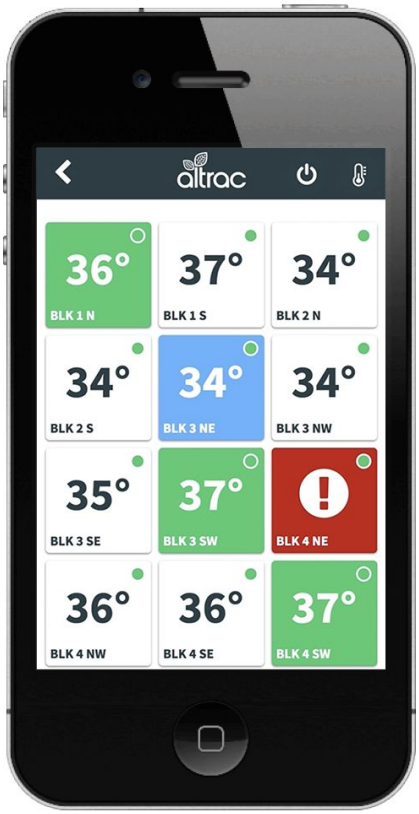
An AutoStart controller is required. The **ST-100** uses industry standard practices to control AutoStarts of all makes and models including Murphy Prolite, Cascade, MPC-20, PV-101, and several versions produced by Orchard Rite. The **ST-100** maintains all engine protection features of the factory installed AutoStart controllers including warm up, cool down, and engine warnings such as high oil temperature.

The Altrac **ST-100** ships with an advanced 40' digital temperature probe, and turns each wind machine into a high tech weather station. We record and store temperature readings over multiple years enabling you to identify cold spots and understand orchard frost characteristics.

The digital probe is wrapped in a rodent resistant nylon sheath and does not require field calibration. Currently, the factory supplied analog probes must be re-calibrated annually, usually by dunking the probe in a milk jug filled with ice water. Altrac has collected data that show due to variation in methodology and human error, the milk jug technique leads to variation is calibration by as much as +/-5*F. Altrac's probe is accurate to +/-0.9F and does not require calibration.

Monitor Equipment from Multiple Ranches

The most powerful feature of the Altrac system is the ability to monitor status of all wind machines from multiple ranches on a single screen. In the smart phone image below, each square tile represents an individual wind machine. The display shows the machine name and the current ambient air temperature measured by the digital probe. For each machine, the ranch overview page displays:



- Ambient air temperature
- Engine state
  - White Tile = Engine Off
  - Blue Tile = Engine Warm Up Cool Down (Low RPM)
  - Green Tile = Engine Full Run (High RPM)
  - Red Tile = Engine Failure (Ambient Temp < Start Temp and the engine is not ON)
- AutoStart Status
  - Armed
  - Disarmed

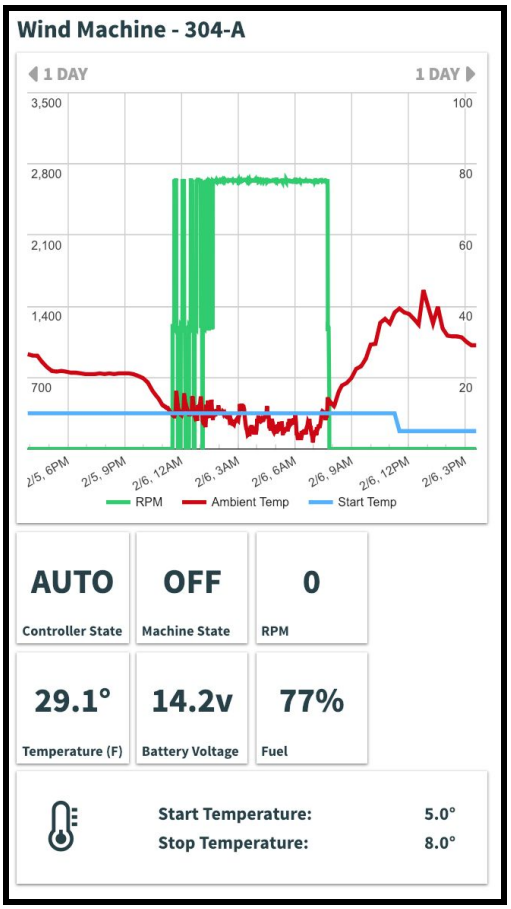
A green dot in the upper right corner of the tile indicates the AutoStart is armed, and the switch on the engine is in AUTO position. A yellow dot signals low battery or non severe engine issue.

Absence of a green or yellow dot means the AutoStart switch on the engine is in OFF or MANUAL position. This is an important safety feature as one very common failure mode is caused by maintenance personnel forgetting to reset the switch to AUTO after service.

This simple display enables you deploy crews precisely to machines with engine failure instead of driving around looking for issues. With the appropriate process changes, Altrac users report savings of 25-40% on frost night surveillance labor.

View Real Time Data from Individual Machines

To view information for a specific machine, click on the device tile to drill down and view a graph that displays ambient temperature (RED), engine RPM (GREEN) superimposed against pre-set engine start temperature (BLUE) for a 24 hour period. Below the graph additional tiles display:



- Controller State
- Machine State
- Engine RPM
- Ambient Temperature
- Battery Voltage
- Tank Fuel level (diesel or propane)
- Start Temp and Stop Temp

Users with the appropriate permissions are able to adjust Start and Stop Temperatures from this screen or click the Machine State tile to turn the machine off.

Banners display engine failure codes and are red for severe issues that stop the wind machine from starting, and yellow for non-severe issues that require attention such as low battery voltage.

Click on the < 1 DAY button to display the previous 24 hours of machine operational data or click on the graph to choose specific date ranges. Altrac keeps historical data about temperature and engine RPM for 2 years which can be downloaded for analysis.

Remotely Start / Stop Multiple Machines

Another important labor saving feature of the Altrac **ST-100** is the ability to start or stop multiple wind machines in a single operation. This capability is very useful during adverse weather conditions such as freezing fog or high winds to prevent damage to crops or the machine.

With legacy AutoStart technology, machines often run 30 to 60 minutes after sunrise before the stop temperature signal is triggered. Altrac enables you to shutdown groups of machines at sunrise with a single click. Generally, the temperature does not decrease while the sun is on the fruit. However, if the weather changes, and the temperature dips below the start threshold, the normal AutoStart function will turn the machines back on.

Auto shutdown of your machines at dawn can save ~15 hours runtime per machine or $506 in propane cost annually. Proactive engine run-time management enables Altrac clients to achieve fuel savings of 12% annually and help payback the controller investment in 18 months.

Change Temperature Settings

The **ST-100** enables farmers to remotely adjust start and stop temperatures for multiple machines in a single operation. This is important because as the season progresses, certain fruits, like citrus, are more resistant to frost damage as they ripen and sugar content increases.

Ranch managers can identify blocks of ripening fruit and adjust the start/stop settings remotely, rather than driving around programming individual machines. The manual re-programming of temperature settings can be tedious, especially when a ranch has multiple machine vendors installed. Often the result is inertia, and machines are left at original temperature settings. The ability to quickly reset temperatures saves fuel and is also useful to make adjustments when a strong inversion layer causes frequent engine cycling.

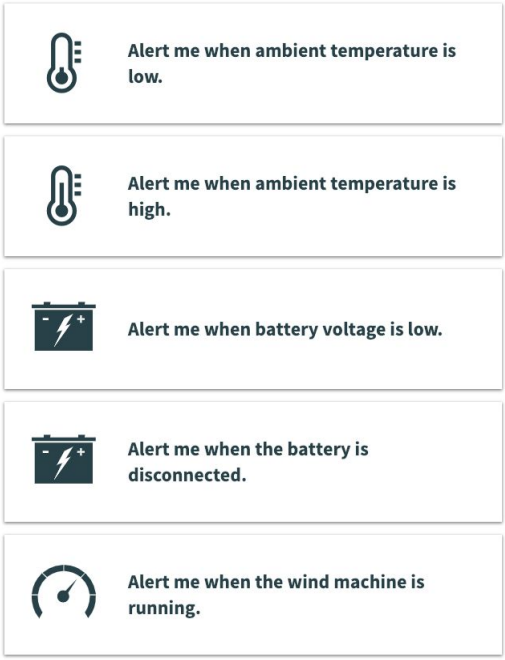
Send Alerts via Email or Text

Another useful feature of the Altrac system is the ability to send alerts via email or SMS text. Alerts can be directed to anyone on the ranch team about temperature, battery voltage, or wind machine status.

The Altrac system enables you to confirm which blocks on the ranch are the coldest. Best practice is to pick 2-3 of the cold spots to trigger a Low Temperature alert. Then the ranch manager can view the main display to check engine operational status for his assigned wind machine blocks.

A major source of AutoStart failure is low voltage or stolen batteries. Alerts on battery status can be addressed before a frost night occurs, potentially saving thousands of dollars of fruit damage.

Users can create custom alerts based on different rules and Altrac is expanding this capability to monitor all machine characteristics.



Frost Night Report

An email report is sent each frost night to summarize operational data for all machines. With traditional machine surveillance practices, most operators have no idea when or how long the wind machine runs on a given frost night. Either the machine was on or off when they drove by and no records are kept. The information gathered by Altrac makes it easy for a ranch manager to debrief with his team about performance. Many organizations also monitor total runtime metrics for individual machines to prioritize

Run Report

November 19, 2018

Group	Device Name	Start Time	End Time	Minimum Temp (F)	Below 32F (min.)	Fuel Level	Cycles	Run Time
Fresno West	Bispo #1	5:38 AM	6:19 AM	31.5	33	63%	1	0 h, 41 min
Fresno West	Fred #1	3:02 AM	7:04 AM	31.3	76	59%	4	1 h, 13 min
Fresno West	Fred #2	1:41 AM	7:32 AM	31.5	85	34%	7	2 h, 16 min
Fresno West	Mazmainian #1			36.7	0	71%	0	
Fresno West	Mazmainian #2			32	22	68%	0	
Fresno West	Mazmainian #3	2:27 AM	7:04 AM	31.7	52	75%	3	3 h, 8 min
Fresno West	Sullivan #1	3:13 AM	6:28 AM	31.7	47	65%	3	1 h, 22 min
Fresno West	Sullivan #2	5:32 AM	6:08 AM	31.7	9	63%	1	0 h, 35 min
Madera	Headquarters #1			28.8	406	43%	0	

units for fluid level checks and other maintenance.

Operational Reports

Users have the ability to create operational reports over different time periods including: hours run, number of cycles, fuel consumption, hours run after sunrise, etc. These reports are useful for maintenance planning and superior to writing the engine run counter results on the panel door at the end of the season. Data can be downloaded to excel for further analysis.

Ranch	Name	Total Frost Nights	Total Runtime (Hr)	Total Cycles	Runtime /Night (Hr)	Cycles /Night	Runtime /Cycle (Hr)	Runtime After Sunrise (Hr)	Runtime After Sunrise
Sentinel Butte	BLK 1 N	32	127	68	4.0	2.1	1.9	14.3	11.3%
Sentinel Butte	BLK 1 S	24	66	45	2.8	1.9	1.5	10.8	16.3%
Sentinel Butte	BLK 2 N	31	87	79	2.8	2.5	1.1	10.0	11.5%
Sentinel Butte	BLK 2 S	30	79	100	2.6	3.3	0.8	8.0	10.2%
Sentinel Butte	BLK 3 NE	28	92	88	3.3	3.1	1	11.7	12.7%
Sentinel Butte	BLK 3 NW	29	91	78	3.2	2.7	1.2	13.3	14.5%

Cellular Connectivity

Altrac's cellular modem connects your wind machines to the cloud. Pricing includes five years of 2G/3G/LTE data plan, and *there are no additional subscription fees*. Mounting on the tower ladder above the tree line is normally sufficient to obtain signal in most locations. A powerful directional antenna is available for remote ranches.

Altrac uses AT&T as the primary network vendor, and T-Mobile as backup for extra reliability. Each wind machine has its own cellular modem which is superior to radio based solutions as there is no single point of failure.

During normal conditions, the modem connects to the network every 15 minutes. As the temperature nears the start threshold, sampling occurs every 60 seconds. Device settings are stored in firmware, so if the cellular connection is lost, the system will operate with these values until a network connection is re-established.

Extensive testing was performed to determine system reliability. The modem selected has a "heartbeat" and a sentinel program which will automatically reset the unit when conditions warrant.

The modem is packaged in a rugged enclosure which complies with the IP67 standard for dust resistance and immersion in up to 3 meters of water. The UV resistant cabling feeds down the tower to the engine. All wiring used is between 20-18 AWG to make it easy for anyone to repair cables that have been severed.

Accessory Port

The Wind Machine Station has an accessory port that accepts either a propane (LPG) or diesel level sensor. Altrac is expanding the port to accommodate other use cases like soil moisture, wind speed, or leaf wetness.

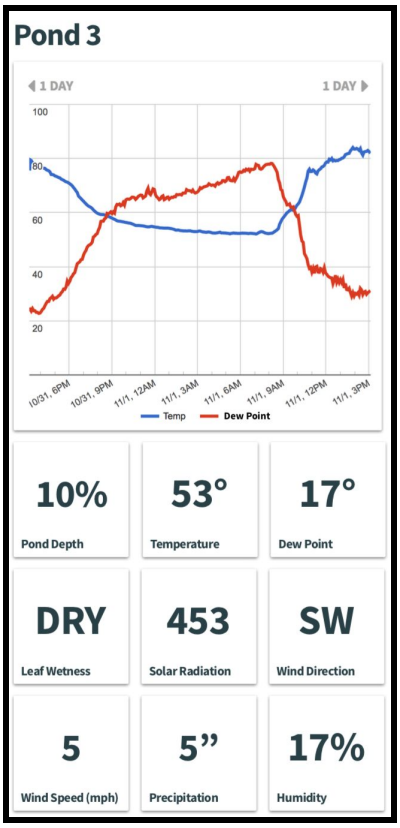
Automotive Grade Components

Altrac uses automotive grade DEUTSCH style environmentally-sealed connectors designed for cable to cable applications on the wind machine engine. These connectors are designed for harsh environments where dust, dirt, moisture, and vibration can damage electrical connections.

Altrac uses DoD grade solid barrel machine terminals on crimped pin connections to withstand engine and tower vibration stress. All wiring is protected by high temperature nylon loom. PCBs are designed with automotive grade components to lengthen lifespan of the hardware. Assembled and tested in the USA in California.

Integration with other Systems

Altrac has a open API that facilitates integration with other vendors and systems. We use SDI-12, RS-485, and RS-485 protocols to integrate with technologies such as the Sentek moisture probe, Davis Weather Stations, and Campbell Scientific Weather Station. The adjacent picture shows weather station integration with the Altrac smartphone application.



We are also in discussion to integrate with farm management systems such as Ag Code and Irrinet. If you would like access to your data, Altrac can provide you with a personal API or csv of your data at any time.

Altrac is open to working directly with hardware manufacturers to develop solutions tailored to suit their specific need. We currently work directly with Amarillo Wind Machine, Blueline Manufacturing, HF Hauff, Jackrabbit Equipment, Vamco Limited, Wenatchee Wind Machine Service, with many partnerships in development.

Cost Justification

The return on investment of the Altrac system is derived from three factors:

- Fuel Savings
- Labor Savings
- Frost Damage Prevention

To begin our analysis of a typical Altrac California Citrus implementation, consider the following ranch characteristics:

Value of Crop/Acre [1]	$7,632
Acres	500
Acres Covered by Each Wind Machine	12
Number of Wind Machines	42
Crop Value/Wind Machine	$91,584
Frost Nights	30
Total Wind Machine Nights	1250
Percentage Failures	5%
Total Failures / Year	63

[1] USDA Citrus Fruits 2018 Summary report, the packing house value of California oranges.

Fuel Savings

As discussed previously, Altrac enables you to shutdown groups of machines at sunrise with a single click. Data collected over the past 2 years indicates that 12.4% fuel savings are achievable by stopping wind machines at dawn as the temperature rises. The run report below is calculated using the following inputs:

- Cost of LPG Fuel: $2.50
- Gallons/HR Consumed: 13.5

Name	Total Runtime (Hr)	Runtime After Sunrise (Hr)	Gallons After Sunrise	Cost of Fuel
BLK 1 N	127	14.3	193.2	$483.10
BLK 1 S	66	10.8	145.5	$363.66
BLK 2 N	87	10.0	135.4	$338.59
BLK 2 S	79	8.0	108.4	$271.00
BLK 3 NE	92	11.7	157.7	$394.27
BLK 3 NW	91	13.3	179.0	$447.49
BLK 3 SE	90	10.7	143.8	$359.54
BLK 3 SW	100	14.8	199.2	$498.00
BLK 4 NE	144	16.5	222.9	$557.24
BLK 4 NW	66	8.8	119.1	$297.85
BLK 4 SE	102	13.8	186.8	$466.93
BLK 4 SW	171	19.4	261.6	$653.96
Rayo BLK 23 NE	94	10.0	135.3	$338.25
Rayo BLK 23 NW	106	13.5	181.7	$454.30
Rayo BLK 23 SE	89	11.1	150.5	$376.16
Rayo BLK 23 SW	67	7.7	103.9	$259.76
Average	98	12.1	164.0	$410.01
Grand Total	1,572	194.4	2624.0	$6,560.11

Average fuel savings per wind machine with an Altrac device is $410 per year.

Labor Savings

Typically a 500 acre grove with wind machines every 12 acres (42 wind machines) requires 2-3 ranch hands to provide frost surveillance duties at the following OT rates:

- 30 night / year x 8 hrs / night x 3 men x $30 / hr = $21,600 year
- With process changes it is possible to reduce surveillance labor by 50% = $10,800 year

Average labor savings per wind machine with an Altrac device is ~$257 per year.

Frost Damage Prevention

Altrac has gathered data during hundreds of frost nights and thousands of wind machine startups in California, Oregon, and Washington. Our data indicates that wind machines with an AutoStart fail to start 5% of the time.

- 30 frost nights x 42 wind machines x 5% failure rate = 63 AutoStart fails / season

The frost damage profile will vary on the severity of the engine fail, how quickly it is detected, and how fast it is repaired. Usually the surveillance crew will identify a dead machine within 2 hours. If major repairs are necessary, add 4 hours to dispatch a mechanic to the site.

Fruit damage occurs when the temperature falls below 28°F. Without the real time alert provided by the Altrac device, fruit can be exposed to freezing temperatures anywhere from 2 to 6 hours. Most growers know intuitively that saving that two hours can make or break your crop on critically cold nights.

Assume the damage profile below where 5 failures on freezing nights cause 1% and 5% damage respectively.

Crop Damage %	Cost of Damages Per Event	Events	Total Damage
0%	$0	56	$0
2 hr < 28°F 1%	$916	3	$2,748
4 hr < 28°F 5%	$4,579	2	$9,158
10%	$9,158	0	$0
15%	$13,738	0	$0
20%	$18,317	0	$0
		Total 63	**$11,906**

Average frost damage savings per wind machine with an Altrac device is ~$283 per year.

To summarize the annual savings for a 500 acre Citrus ranch with 42 wind machines equals:

- 42 machines x $410 Fuel Savings/Machine/Year = $17,220
- 42 machines x ~$257 Labor Savings/Machine/Year = $10,800
- 42 machines x ~$283 Crop Loss Prevention/Machine/Year = $11,906

$39,926

Total savings per wind machine with an Altrac device is ~$951 per year.

The average cost of the Altrac system is $1,500 including installation and five year data plan. For the hypothetical Citrus ranch in this example, the total cost to upgrade the ranch to Altrac devices is 42 x $1,500 = $63,000. Cash flow for a three year period is shown below and the payback period is 1.5 years.

- Year 1 = $23,074
- Year 2 = ($16,852)
- Year 3 = ($39,926)
- Three Year Cumulative Savings = **($56,778)**

Clients

Altrac has numerous clients in California, Oregon, Washington, and Chile. Examples include:

Apple	**Citrus**	**Vineyard**
Zirkle	Wonderful Citrus	Blue Heron Wine
K.Matheson	Limoneira	Mesa Vineyards
Chiwana Vista	Gillette Citrus	Sebastiani Wines
Borton Fruit	Fowler Packing	
AK Orchards	Kausen Farms	
Wyckoff		

Partners

Amarillo Wind Machine	www.amarillowind.com	559-592-4256
Blueline Manufacturing	www.bluelinemfg.com	509-248-8411
HF Hauff	http://www.hfhauff.com	509-248-0318
Rogue Valley Farm Equipment		541- 826-8500
Tecnipak	www.tecnipak.com	(56 22) 496 5600
Vamco Limited	www.vamcoltdinc.com	559-562-5185
Wenatchee Wind Machine Service	www.wenatcheewind.com	509-669-2511

Contact

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