Powering Up for the Future

WEG direct-drive wind turbine AGW 110/2.1MW

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As the need for electricity continues to grow around the world, meeting this demand requires renewable energy technologies. Brazilian company WEG, a longtime leader in design and production of electric machines, has the expertise to deliver these renewable energy systems and components. WEG Energy leverages ANSYS solutions throughout the design process — and even during product operation — to develop reliable renewable energy equipment.

Taking Turbomachinery Simulation to the Next Level
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The size of the global renewable energy market will reach approximately $1062.4 billion by the end of 2024, growing at a compound annual growth rate of 13.1 percent from 2018 to 2024, according to market research company Envision Intelligence. To decrease greenhouse gas emissions while meeting increasing demand for electricity, many countries are investing in renewable technologies for their power plants. WEG supplies solutions for such plants.

Founded in 1961 as a small factory producing electric motors, today WEG is a global manufacturer and provider of a range of energy solutions.

Renewable energy technologies within WEG's Energy division include wind turbines, turbogenerators and hydrogenerators. Engineers must produce these high-quality products according to demanding schedules and within cost constraints. Testing these large, complex machines at every stage of development would be too costly and time-consuming, so the team applies engineering simulation from the early stages of the design process and throughout product development. WEG engineers rely on ANSYS' comprehensive solutions for structural, electromagnetic and thermal simulation.

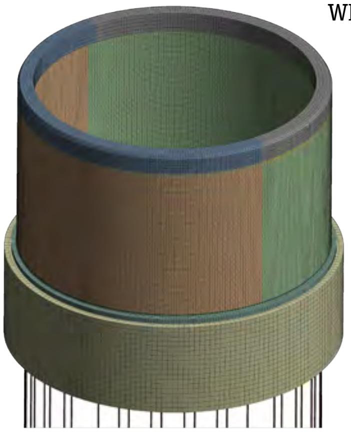
> **"The WEG team applies engineering simulation from the early stages of the design process and throughout product development."**

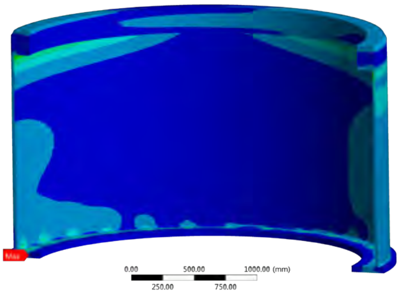
Most of WEG's renewable energy solutions are nonstandard designs that must be customized according to each project's requirements and operating conditions. This level of customization requires flexible, comprehensive and accurate engineering simulation. For WEG's new 4 MW direct-drive wind turbine platform, engineers used ANSYS Mechanical and ANSYS Maxwell simulation solutions from the start of the design process and throughout development. Turbogenerators in steam turbines that are used in thermoelectric plants have a high power density. This intrinsically generates excess heat that must be properly cooled. WEG engineers used ANSYS CFX computational fluid dynamics (CFD) simulation software for thermal management, resulting in efficiency improvements. For hydroelectric generation, the hydraulic turbine design requires combinations of ANSYS BladeModeler, ANSYS TurboGrid, ANSYS CFX and ANSYS DesignXplorer to explore the turbine construction parameters combined with system variables to develop efficient, robust equipment.

Doubling Wind Turbine Output

With increased competition in the wind power market, WEG is developing a 4 MW direct-drive wind turbine that almost doubles the output of its current 2.1 MW platform. Being developed in partnership with WEG engineers in the U.S., this new, larger turbine exhibits high efficiency and low maintenance.

High dynamic loading caused by increased power output required ANSYS Mechanical for structural simulations of the wind turbine's various components. The main challenges in designing the rear chassis of the wind turbine were the geometrical complexity of the component and the evaluation of many different load cases. Using ANSYS Mechanical and ANSYS DesignXplorer, WEG engineers simulated all structural aspects of the part, including the evaluation of critical welding spots that have high loads and manufacturing process characteristics, to produce a tough, reliable component.

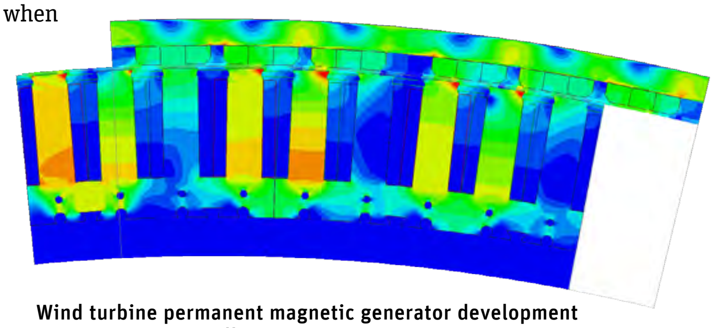




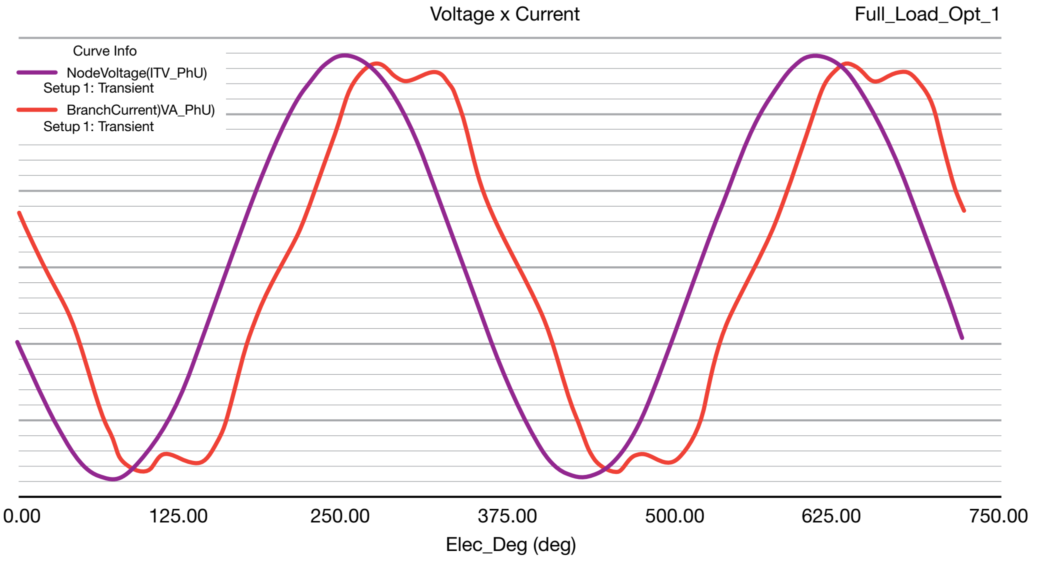
Nacelle tower-top adapter (left). Evaluation of neck stress and welding point (right).

The nacelle tower-top adapter, which couples the top of the concrete tower to the bottom of the nacelle and its yaw bearing, must withstand extreme loads, avoid plastic deformation and not slip during the wind turbine's lifetime. Engineers used structural simulation to evaluate stresses at the neck and at welding points and ANSYS nCode DesignLife for fatigue failure analysis.

In addition to ANSYS Mechanical, WEG engineers used ANSYS Maxwell extensively to simulate low-frequency electromagnetic fields to evaluate torque, induced voltage, losses and magnetic core saturation. One of the key criteria when developing electrical equipment such as wind turbines is to minimize harmonic currents between the generator and the power converter. To maintain low total harmonic distortion (THD), engineers used simulation to analyze magnet positioning to determine the generated voltage and harmonic spectrum.



Wind turbine permanent magnetic generator development using ANSYS Maxwell



Voltage and current of the wind turbine with a full load operation

Overall, ANSYS simulation solutions proved to be invaluable in the development of the 4 MW platform, enabling the engineering team to rapidly validate and refine the design.

Developing and Evaluating Electric Generators

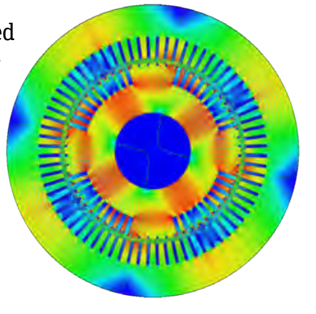
WEG has been producing electric generators for over 30 years. For each new product, engineers evaluate every innovative feature through in-depth simulation. For example, a new project usually requires thermal analysis because an increase in power output or a machine size reduction intrinsically impacts the machine's thermal heating versus cooling balance.

To illustrate one innovation, WEG wanted to replace the steel cover that contains the rotor coil head with an alternative material in a new line of turbogenerators. The engineering team explored the use of a pre-impregnated composite material in the form of a banding tape instead of a retaining ring. They used ANSYS Mechanical to evaluate the radial displacements of the banding for two imposed conditions: the strain in the components of the coil head and the residual contact pressure of the banding. The result was a fully validated component with a lower rotor mass that is also cost-effective to manufacture. New materials, like the composites in this case, can reduce feedstock costs by as much as 77 percent and wound rotor manufacturing costs by 18 to 20 percent.

> “Ventilation losses were reduced by 23 percent, and the total weight was reduced by 14 percent.”

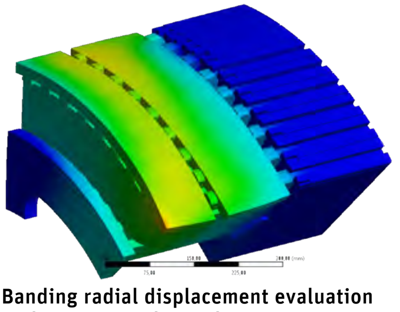
WEG generator installed at end-user plant

Besides structural improvement in these generators, WEG also wanted to increase the efficiency of the generator cooling system through better air distribution. WEG engineers used ANSYS CFX to determine the airflow through the rotor and stator coils to detect any hot spots. The result was a more uniform thermal distribution, leading to increased machine performance and reduction of windage (air resistance) losses. Ventilation losses were reduced by 23 percent, and the total weight was reduced by 14 percent.

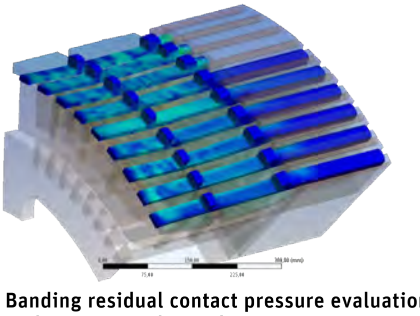


Cylindrical pole generator simulation using ANSYS Maxwell showing induction and flux lines for an asymmetric model with full load operation

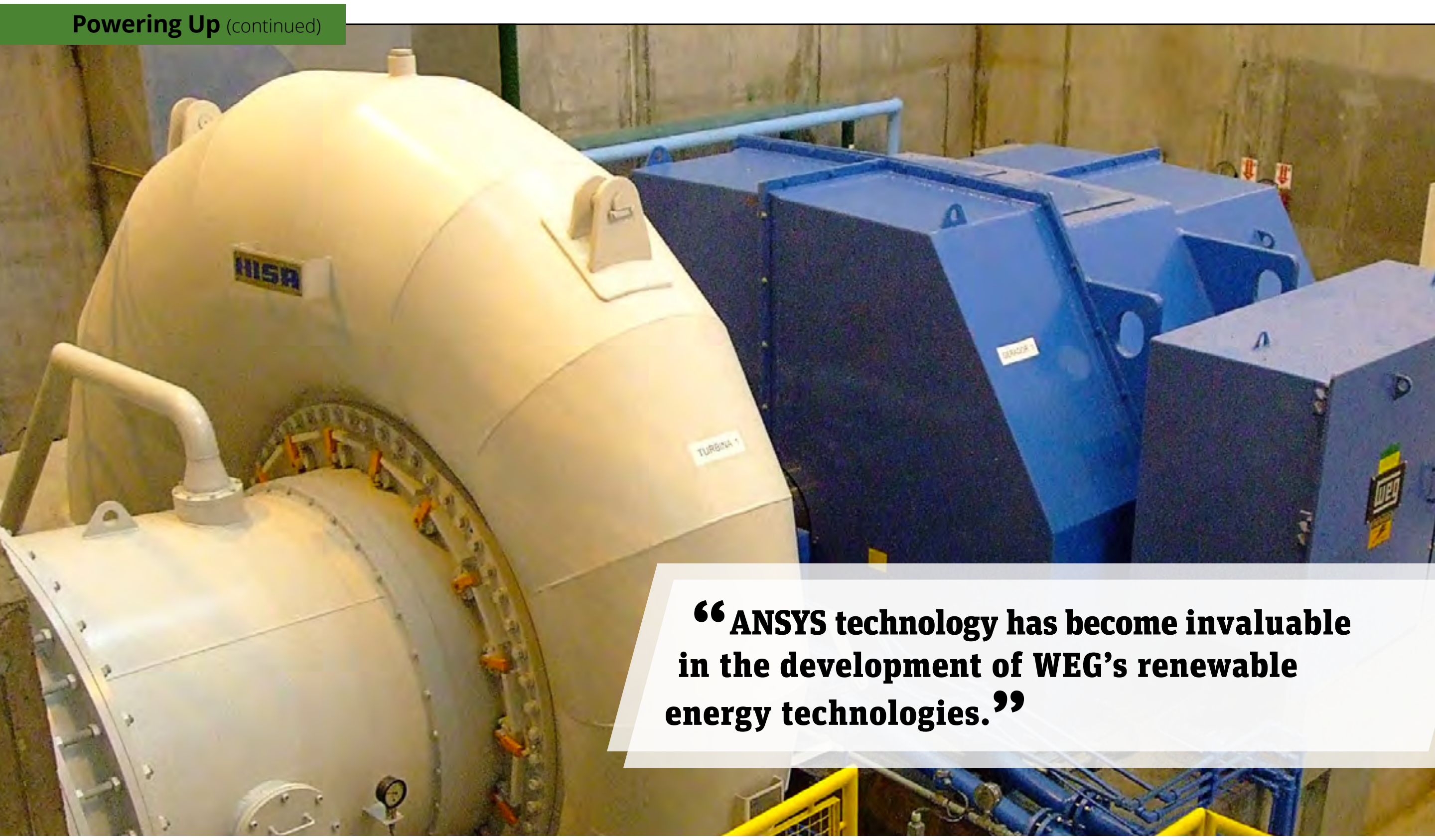
For electromagnetic analysis during development, ANSYS Maxwell provides valuable insights about the generated voltage as well as magnetic core saturation and losses. Additionally, the versatility of Maxwell helps WEG engineers to evaluate design alternatives, predict performance and diagnose potential faults under certain operating conditions. For instance, if a machine shuts down due to a stator coil short circuit, or if the stator requires repair or specific coils need to be replaced, the machine might be out of service for some time. To continue operation, the failed stator coils can be disconnected as a temporary repair. However, the resulting nonsymmetrical current distribution tends to cause overheating. Using the ANSYS Maxwell transient solver, WEG engineers can determine the effect of the temporary repair on the machine’s performance by carrying out a detailed electromagnetic analysis to predict the phase and path current distribution, estimate the harmonic impact and calculate the derating factors. The derating factor indicates the level to which the machine output power must be limited based on the temporary repair. ANSYS tools enable WEG engineers to view complex phenomena and address any issues.



Banding radial displacement evaluation with ANSYS Mechanical



Banding residual contact pressure evaluation with ANSYS Mechanical



> **"ANSYS technology has become invaluable in the development of WEG's renewable energy technologies."**

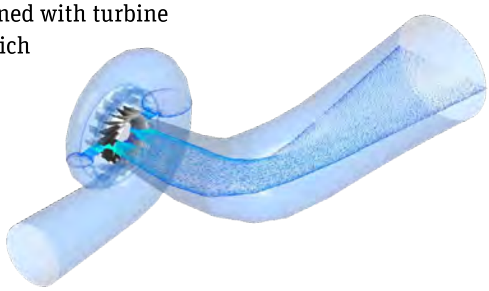
Francis turbine and WEG generator during a commissioning event

Hydraulic Turbine Design Exploration

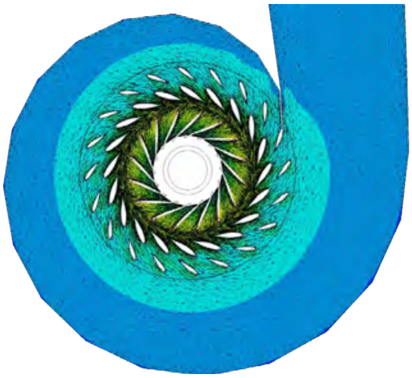
The fluid dynamics of a hydraulic turbine during operation are quite complex. For hydropower generation, the location and the unique geographic characteristics of each project affect conditions like pressure, water flow rate and water head level. Simulation is used to effectively account for all the parameters involved and can be combined with turbine construction parameters, such as in a Francis turbine, which includes radial and axial flows.

Using ANSYS CFX, WEG's engineers examined the working pressure fields and velocity profile to estimate the turbine parameters for a wide range of operating conditions. Using ANSYS Workbench, they parameterized components such as stay and guide vanes and easily deployed ANSYS turbo tools to evaluate important characteristics through meridional cross section and blade-to-blade section. This enabled engineers to virtually observe the water flow through the hydraulic contour and blade profiles.

Optimizing the efficiency of a hydraulic turbine for a wide range of operating conditions is a challenging task. To assist in creating the most efficient turbine, engineers use ANSYS CFX to generate a turbine Hill Chart for each nonstandard project, consisting of efficiency rate curves that describe the performance for different combinations of operational conditions. WEG's engineers input data from simulations carried out using CFX in conjunction with ANSYS DesignXplorer into this chart.



Complete model of Francis turbine simulated with ANSYS CFX



Velocity simulation for stay guide vanes and runner blades of a Francis turbine

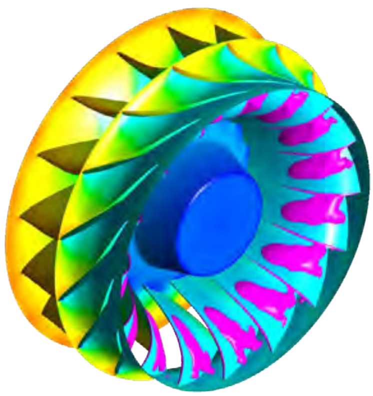
Turbomachinery Simulation 10x
ansys.com/turbo-10x

This enables them to explore and experiment with a range of different machine parameters such as blade shape, guide vane positioning, and spiral case and draft tube behavior.

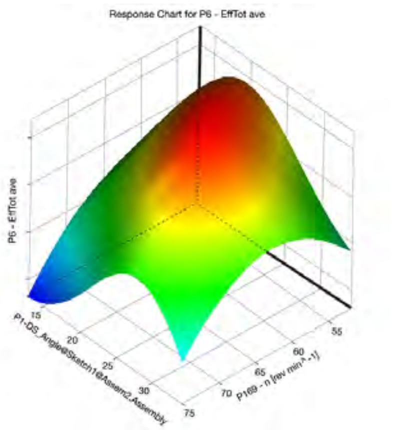
The engineering team also carries out complex studies, including the verification of runaway turbine speed and the existence of cavitation regions, which can damage the runner blades. In the event of runaway turbine speed, critical parameters, such as overspeed and spiral case overpressure need to be deeply analyzed to ensure safe mechanical levels.

Virtual models help to evaluate these parameters before machine manufacture. One method of studying cavitation is to identify and evaluate areas of low water pressure in the liquid state. However, the most accurate method is to study the state of the water (from fluid to vapor) as the machine operates in these low-pressure areas. Simulation is an effective method of doing this.

Having discovered the most efficient combination of input parameters on a virtual model, WEG makes the product and gets field data to close the engineering information loop. Using simulation, WEG can manufacture hydro turbines with the confidence that they will be reliable, efficient, high-performing machines.



Francis turbine runner design simulation using ANSYS CFX



Francis turbine Hill Chart curve, wherein red indicates the better efficiency values

Expanding the Use of ANSYS Simulation Solutions

ANSYS technology has become invaluable in the development of WEG's renewable energy technologies, particularly in the design of customized and nonstandard solutions. Simulation enables the engineering team to minimize uncertainty and mitigate risk. WEG engineers use simulation for product inception, design iteration, virtual prototyping and even forensic analysis after operation. It is applied to most of the company's products to determine the optimal design based on a wide range of physics. WEG Energy is expecting to expand its use of engineering simulation; the team that uses ANSYS software is growing. In WEG's vision of the future, engineers anticipate using ANSYS tools in digital twins, which are real-time, virtual copies of operating machines.

At WEG Energy division, simulation helps engineers cut time and cost from the development process and create reliable, high-performance machines. In 2018, Milton Castella, director of engineering at WEG, accepted the Innovation Brazil Award for WEG. During the ceremony he stated, "In 2016, approximately 50 percent of our revenue was generated with products developed within the past five years." ANSYS has played a vital role in helping WEG achieve this milestone.

ANSYS elite channel partner ESSS provides training in ANSYS simulation software for both beginners and experts.

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