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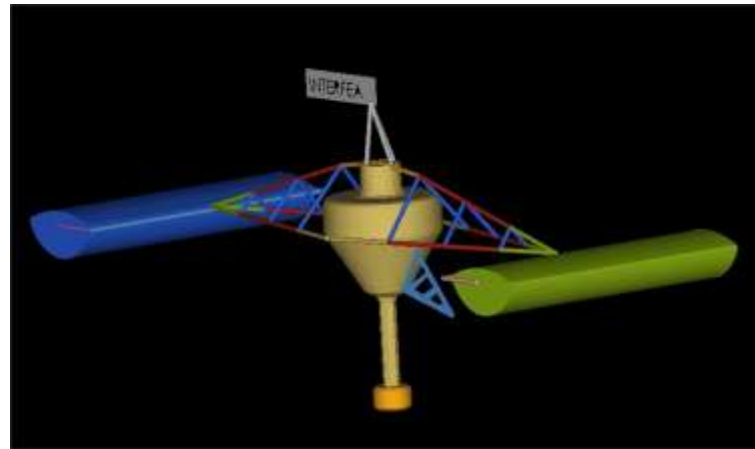
# 4th European HyperWorks Technology Conference



Innovative Engineering Solutions

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October 27-29, 2010  
Palais de Congres  
Versailles, France

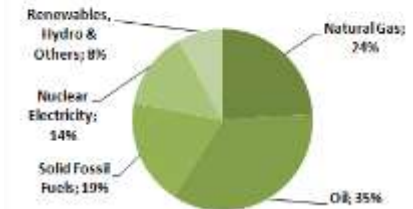


Problem – Need – Ideas – Methodologies - Results

## European Union

“Europe's citizens and companies need a secure supply of energy at affordable prices in order to maintain our standards of living. At the same time, the negative effects of energy use, particularly fossil fuels, on the environment must be reduced. That is why EU policy focuses on creating a competitive internal energy market offering quality service at low prices, on developing renewable energy sources, on reducing dependence on imported fuels, and on doing more with a lower consumption of energy.” “Energy policy for a competitive Europe, europa.eu”

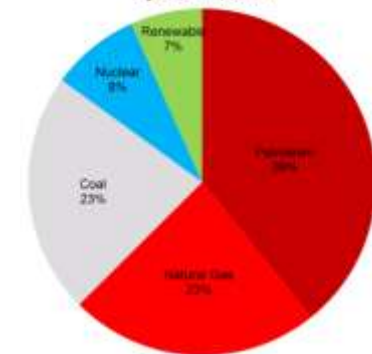
Primary Energy Consumption in the EU



## United States of America

“State-specific energy-efficiency incentive programs also play a significant role in the overall energy policy of the United States. The United States had resisted endorsing the Kyoto Protocol, preferring to let the market drive CO<sub>2</sub> reductions to mitigate global warming, which will require CO<sub>2</sub> emission taxation. The administration of Barack Obama has proposed an aggressive energy policy reform, including the need for a reduction of CO<sub>2</sub> emissions, with a cap and trade program, which could help encourage more clean renewable, sustainable energy development.” Energy policy of the United States

US Energy Consumption by Source, 2007



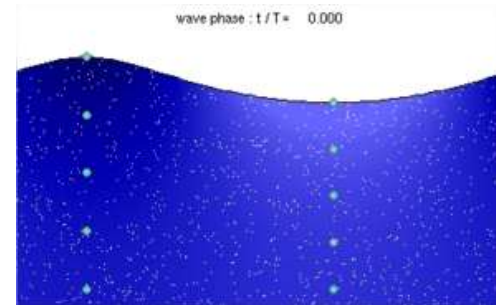
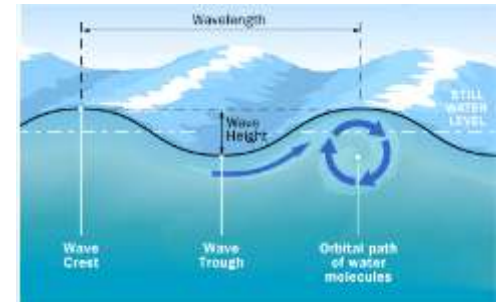
Data source: US Energy Information Administration

## The Phenomenon of waves

Waves are generated by wind passing over the surface of the sea. As long as the waves propagate slower than the wind speed just above the waves, there is an energy transfer from the wind to the waves. Both air pressure differences between the upwind and the lee side of a wave crest, as well as friction on the water surface by the wind, making the water to go into the shear stress causes the growth of the waves.

Wave height is determined by wind speed, the duration of time the wind has been blowing, fetch (the distance over which the wind excites the waves) and by the depth and topography of the seafloor (which can focus or disperse the energy of the waves). A given wind speed has a matching practical limit over which time or distance will not produce larger waves. When this limit has been reached the sea is said to be "fully developed."

In general, larger waves are more powerful but wave power is also determined by wave speed, wavelength, and water density.



- **Wave power formula**

- In deep water where the water depth is larger than half the wavelength, the wave energy flux is

$$P = \frac{\rho g^2}{64\pi} H_{m0}^2 T_e \approx \left( 0.5 \frac{\text{kW}}{\text{m}^3 \cdot \text{s}} \right) H_{m0}^2 T_e,$$

- The above formula states that wave power is proportional to the wave period and to the square of the wave height.
- When the significant wave height is given in meters, and the wave period in seconds, the result is the wave power in kilowatts (kW) per meter of wavefront length.

- **Wave energy and wave energy flux**

- In a sea state, the average energy density per unit area of gravity waves on the water surface is proportional to the wave height squared, according to linear wave theory

$$E = \frac{1}{16} \rho g H_{m0}^2$$

- where  $E$  is the mean wave energy density per unit horizontal area ( $\text{J}/\text{m}^2$ ), the sum of kinetic and potential energy density per unit horizontal area. The potential energy density is equal to the kinetic energy, both contributing half to the wave energy density  $E$ , as can be expected from the equipartition theory. In ocean waves, surface tension effects are negligible for wavelengths above a few decimeters.

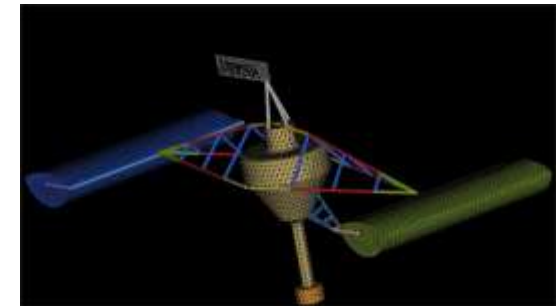
- **Wave power** is the transport of energy by ocean surface waves, and the capture of that energy to do useful work — for example for electricity generation, water desalination, or the pumping of water (into reservoirs).
- **Wave power devices** are generally categorized by the method used to capture the energy of the waves. They can also be categorized by location and power take-off system. Method types are point absorber or buoy; surfacing following or attenuator oriented parallel to the direction of wave propagation; terminator, oriented perpendicular to the direction of wave propagation; oscillating water column; and overtopping. Locations are shoreline, nearshore and offshore. Types of power take-off include: hydraulic ram, elastomeric hose pump, pump-to-shore, hydroelectric turbine, air turbine, and linear electrical generator. Some of these designs incorporate parabolic reflectors as a means of increasing the wave energy at the point of capture. These capture systems use the rise and fall motion of waves to capture energy. Once the wave energy is captured at a wave source, power must be carried to the point of use or to a connection to the electrical grid by transmission power cables.



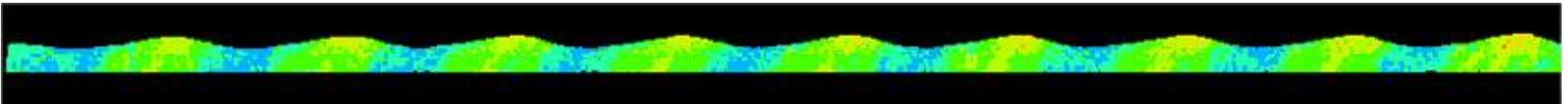
- The need to design a mechanism that could convert the energy of waves into electricity is increasing every day and increase the need for further research and optimization of new ideas as well.
- Many ideas and suggestions have been lined up in recent years to better use of all waves on the planet, each device should be designed and redesigned several times wanting to keep certain standards, Such devices should comply with standards multiple rules, this increasing the cost of research.
- Most times the developing of a mechanism is impossible to move forward for the reason that the technology has not invented solution for calculating the performance and behavior before creating the first prototype.



- The simulation of a small models in a tank can give us a first look of the behavior of the device but can not help us understand the efficiency, the structural analysis, the behavior under special conditions and the interaction of the elements carrying off energy and converted into electrical ( actuators, electrical generators etc)
- In the present software market we can found several software that can do structural - CFD - 1d systems simulations but the issue is that these software are not able to simulate mechanisms with specific data and methods
- The simulation software should have the capabilities in order to calculate the following parameters:
  - An ocean wave formulation - Methodology to create custom waves
  - Equations to solve ALE and to model correctly the wave shape
  - Failure criteria
  - Structural analysis of the construction
  - Composites material
  - The capability to create special elements (spring, actuators)
  - Options to simulate the Dynamic behavior of the device on the waves with the calculation of the 1d systems
  - Option to couple with Optimization codes

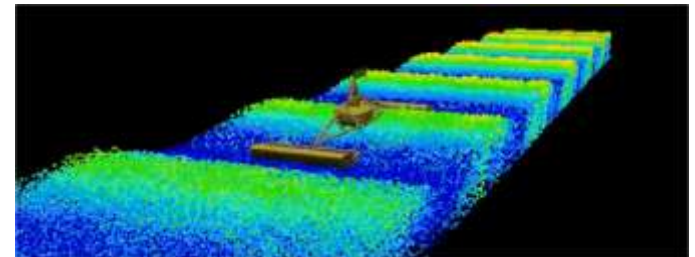
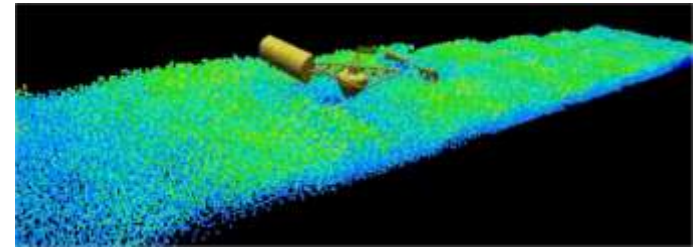


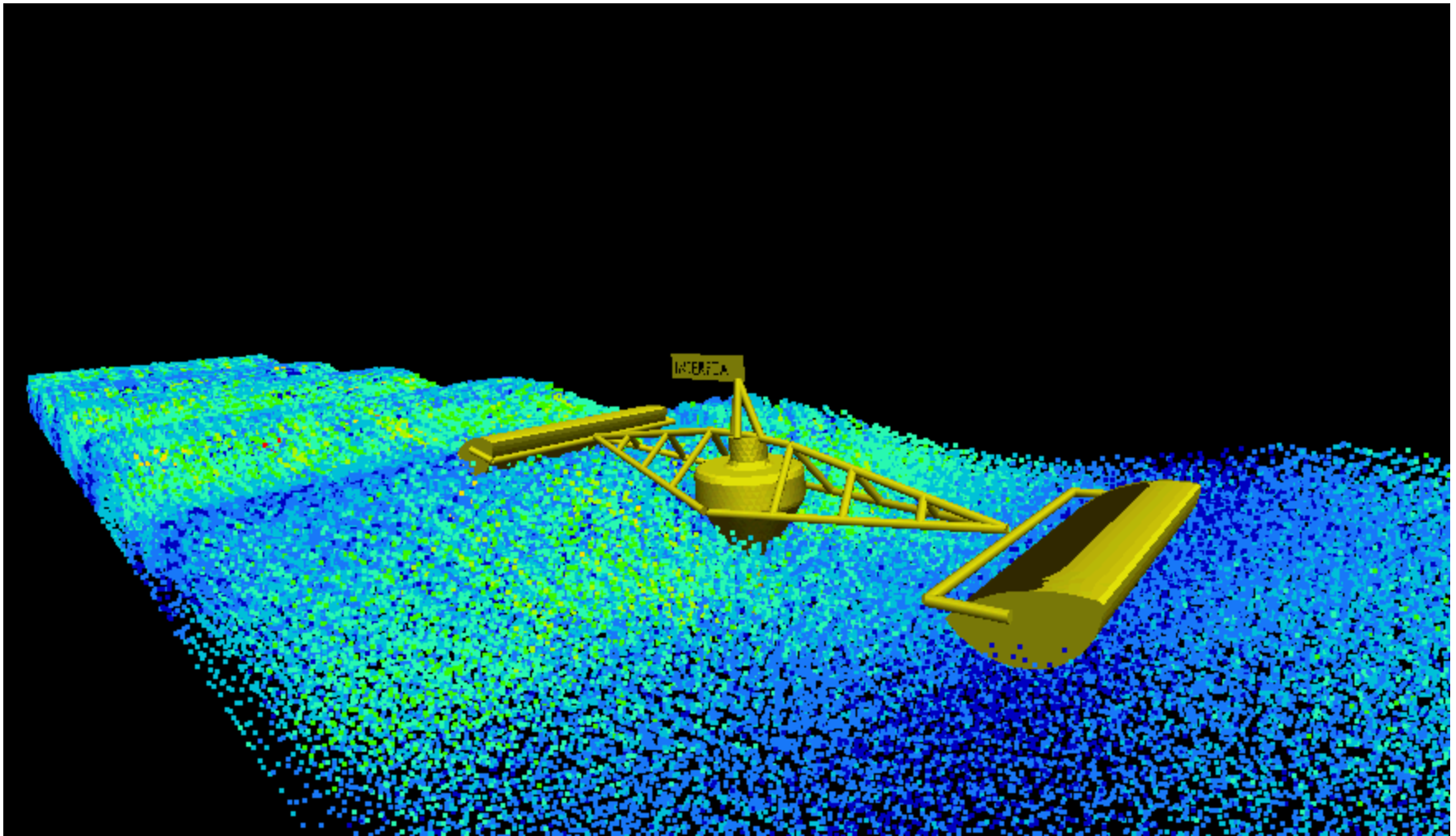
- As the best approach for developing a methodology for solving the problem a dynamic simulation software Radioss from Altair Engineering has selected.
- For the simulation of the ocean waves, a special methodology developed to create any length – height - period of a wave by using SPH to model the ocean. The SPH can replace the need for a CFD code since it can simulate the ocean surface with the accuracy of any CFD solver, also the modelization of the wave by using SPH can reduce the time for solving the simulation since the engineer does not spending time for extreme meshes.
- The solver can couple with 1d simulation software and an optimization software, this opportunity has many benefits for developing such devices, the motion of the device can couple with the 1d simulation software and to export the velocity of the nodes that the actuators are positioning, then the 1 d simulation software can calculate the motion of the actuators and the hydraulic – electrical system, the next step is to send back to the explicit dynamic solver the forces of the actuators and their position for the calculation of the next step.



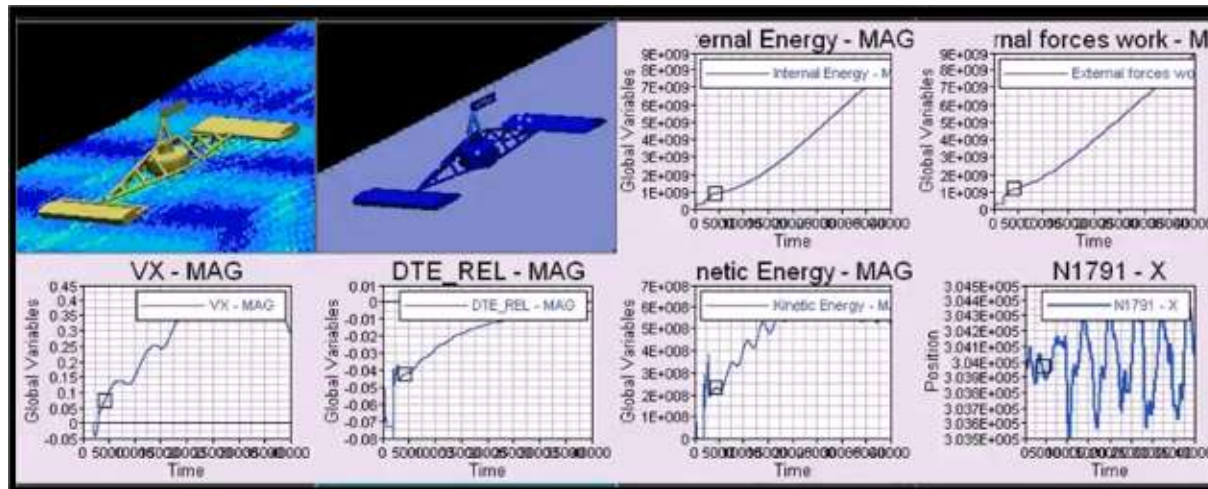
Ocean waves model with SPH

- The benefits from using the explicit dynamic solver Radioss and the coupling options are:
- Better understanding the correct pressure of the hydraulic system for having the best efficiency and to stop any undersea phenomenon.
- Understanding the parameters in design that the engineer has to make for more efficiency ( length - weight etc)
- Calculation of any elements that create the assembly ( steel parts, links, composite materials etc)
- Calculation of any undersea phenomenon
- Same time calculation of the 1d system as well.
- Understanding the interaction between the structural parts and the hydraulic systems, the engineer can change the size of the motors or the generator and study the motion on the same or on a different wave.
- Full Automate optimization of the structural parts and the 1d systems by coupling with Hyperstudy .
- Hyperstudy can optimize the length – weight - shape of the structural parts, pressure of the hydraulic system, size of the actuators, size of any hydraulic component etc fact and accurate, composite parts.
- The capability to find the best place to add the actuators and to create the best link design.

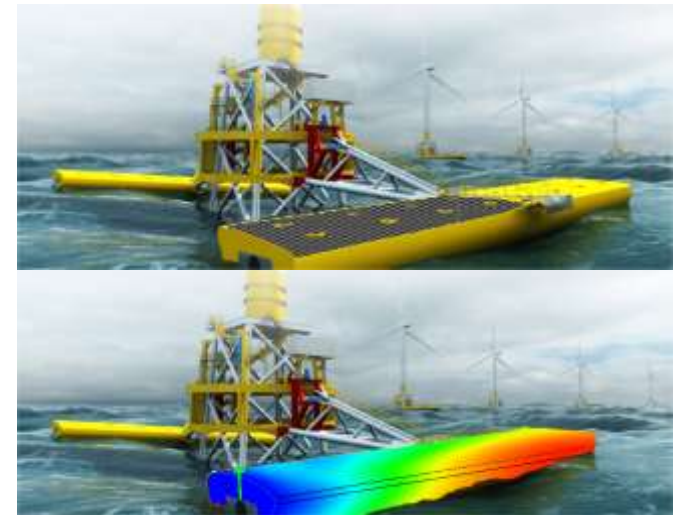
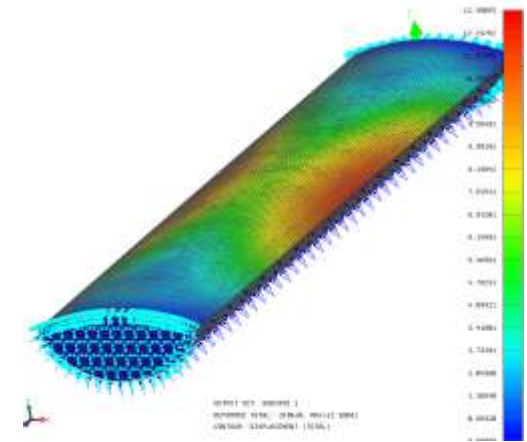




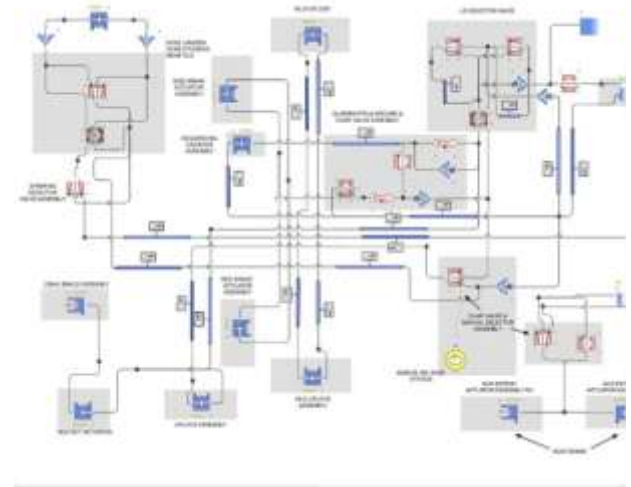
- The engineer can work with several data for creating the best product easily and fast enough.
- Using the high end simulation software can create several simulation with different parameters and to check the different designs in the less time. The capability to redesign the device with out the need to start from the beginning, and to extract important data as velocities, stresses, deformations, hydrodynamic drag, wave crash etc can help him to reach the market faster than any other competitor.
- Hyperview used for post process any result and with Hypergraph created any diagram that could explain the actual interactions of the phenomenon and the human technology.



- The opportunity for optimization of the energy structure is very important especially if the construction is made from composite parts, in this case the composite parts have to be in the service for many year , any impact from woods or any garbage's has to leave the part without any damage, also the strain and the stresses due to the wave impact has to be inside the limits of the part.
- With optistruct we have the opportunity to optimize the best shape for the beam elements, the best point that we could link actuators and also the ideal shape of any other structural member .
- Optistruct is also used for the design and optimization of the floats, the idea to create floats from composites materials took place with the use of optistruct, the last design is 50% less weight and 20% stronger than the first design.

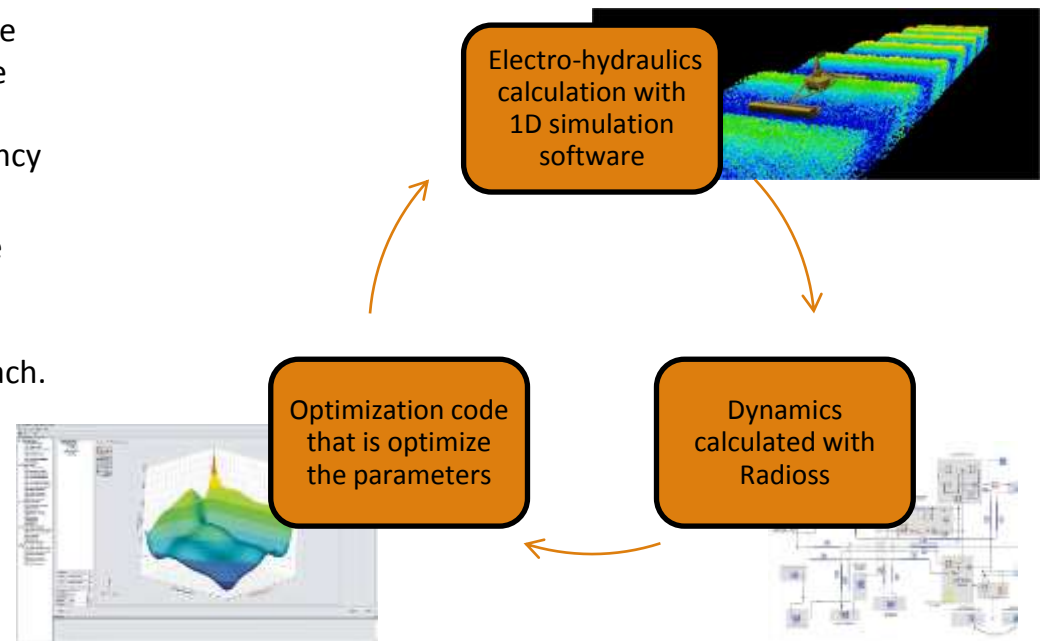


- The wave energy generator produce electricity from the motion of the floats on the wave surface, the ideal production is succeed at the point that the motion of the float is not destroying the height of the wave more than 20% , if the pressure of the hydraulic system is increase then the floats are sink in the waves as a result to have less motion, less motion means less mass of high pressure hydraulic liquid as a result to have less revolutions per minute to the motor, also a complete sequence of the floats on the waves have as result to have less pressure on the hydraulic system even if we are having a height hydraulic liquid mass production.
- The ideal solution has to follow the high efficient field of the hydraulic motor , that means that the pressure and the production of the hydraulic liquid have to follow specific levels for each wave for the maximum efficiency.



# COUPLING RADIOSS WITH 1D SIMULATION SYSTEM

- By coupling Radioss and a 1D simulation software we can calculate the hydraulics and electrical circuits at the same time with the dynamic of the structure, that means that we can increase or decrease the pressure of the liquid or change the actuators dimensions and study the motion of the structure and the efficiency at the same time.
- By coupling Hyperstudy with the above solvers we can optimize all these parameters and create curves that will help us to understand the best approach.



# ECONOMICAL BENEFITS

- The Methodology of simulating an ocean wave generator using an explicit dynamic solver – 1d system simulation software – optimization engine can reduce the cost for developing more than 50 %
- The efficiency of the product can reach the maximum level
- The cost of the material can reduce more than 60 %
- The needs for any composite material that could give more benefits, easily can be study.
- The cost of the Hydraulic components can reduce and reach the most important.
- More benefits can examine on each design case.



# Thank you

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