In a study investigating the use of integrated generators (IG) inside the compressor connected directly to the low pressure shaft, instead of constant speed generators on board aircrafts. The conclusion was that this was not only possible but may very well result in an overall increased electrical power capacity per unit of mass and an overall more efficient engine.

The study was intended as a proof of concept for the use of a generator connected directly to the low power shaft of an aircraft engine in order to produce more electrical power as aircrafts are utilizing more and more electrical systems following the MEA (More Electrical Aircraft) trend. Including replacing everything from hydraulics systems to motor control and air bleed in engines with electrically powered compressors to power the AC system among other things.

The big difference between a conventional system and the one proposed in this paper is the speed of the generator on which it operates. In the proposed system the generator is connected directly to the LP shaft resulting in a varying speed. In a conventional system however a gear box is located on the generator giving it one constant speed to operate at. This gear box is however a very expensive piece of equipment and tend to brake quite frequently and is often the reason for unforeseen delays. This means that in order to utilize the electrical power, power electronics will be needed in order to stabilize the power conditions.

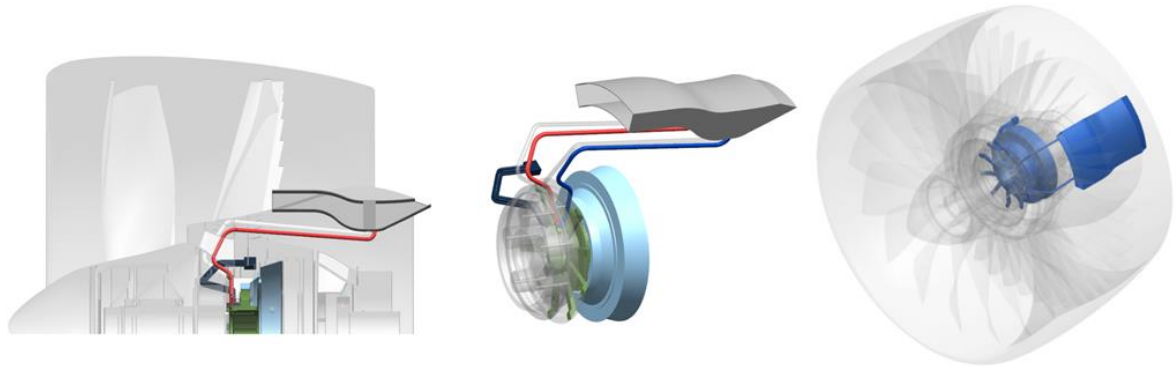

Figure 1: Conceptual sketches of the proposed generator and integrated cooling system.

Before the simulations could start the actual type of generator that was to be used needed to be determined where everything from wiring losses to power ratio was compared between different types of generators. In the end it was however determined that the generator that was to be used was a Permanent Magnet Machine Tooth Multipole (PMMTM). This type of generator offers a high power to weight ratio as well as a structure that is deemed to not be overly complicated to cool. The reason for the simpler cooling than can be found in other generators in due to the fact that all the wiring is located in the stator, this combined with using the right type of magnets in the rotor would allow the generator to operate at extreme temperatures without failure suitable for a generator located inside an aircraft engine.

The first steps to investigate if the IG could serve as a viable replacement for the conventional constant speed drive was done in MatLab using a custom code from LTH. The code served to give a primary glimpse of relative power output between rather than an exact power output. This gave a fast method of comparing different generator layouts and isolating the most important design parameters. After this was done ANSYS Maxwell was used. Here the most promising layouts found in MatLab where replicated and run again. These results confirmed what the results from the MatLab code and a primary design was chosen. This design had 72 slots and 12 poles.

The overall performance where to satisfaction but since the generator needed to run at speeds from as low as 1500 rpm to high speeds of about 7000 rpm the actual output varied heavily as well. The actual demand on the generator meant that it needed to produce 156kW at 1500 rpm, the same as for 7000 rpm. However since power is directly proportional to speed, this meant that the possible output at 700 rpm was closer to 500 kW assuming a maximum current of 500 Amp. This would allow for multiple systems to be replaced with electrical counter parts in order to decrease the aircrafts overall weight improving the fuel economy. As well as offer a possibility of removing air bleed from the engines for dedicated compressors powered by electrical motors.

Some of the overall larger problems with utilizing this type of power source are interestingly enough the varying rpm. As where conventional systems have a pre-determined speed to operate at, here that is not the case. Not only does the frequency and the power output vary, but so does the voltage as well, this could however be fixed with the use of power electronics. Another thing that makes this complicated is the wave pattern of the current, a typical three-phase electrical current will follow a sinusoidal wave shifted 120 degrees between the different phases. Because of the large variety in speed, no such behavior could be created during the simulations adding another possible task for the power electronics.

There where however multiple things that was not investigated during the course of this project, mostly due to lack of knowledge and experience as well as problems with the software that was to be used. These where primarily the following: Optimization of the design, some optimization has as mentioned earlier already been done, it is however very likely that a more efficient layout with a larger power to volume ratio exists. The next thing that needs further investigation is structural solidity, since the generator will be the victim of severe vibration and heat due to its operating environment. The heat transfer and cooling also needs to be investigated further. Initial cooling assumptions has been made but more detailed FEMM testing is still needed. As mentioned power electronics will be needed to deal with the varying electrical output from the generator. Maintenance is another thing that is important and requires further investigation since the generator needs to be able to undergo service every now and then. The economic aspect also need to be looked in further, simply to establish whether or not it is more profitable to replace the conventional system with suggested direct drive. . Lastly but maybe the biggest one is safety since the generator cannot be stopped from rotating without turning of the actual engine.