Inside welding inverters

African Fusion visits Reeflex's Welding's inverter manufacturing facilities in Strydompark, Randburg and talks to Dr Philip Theron – a local inventor and patent holder of inverter-based power equipment and the technical director of Reeflex.

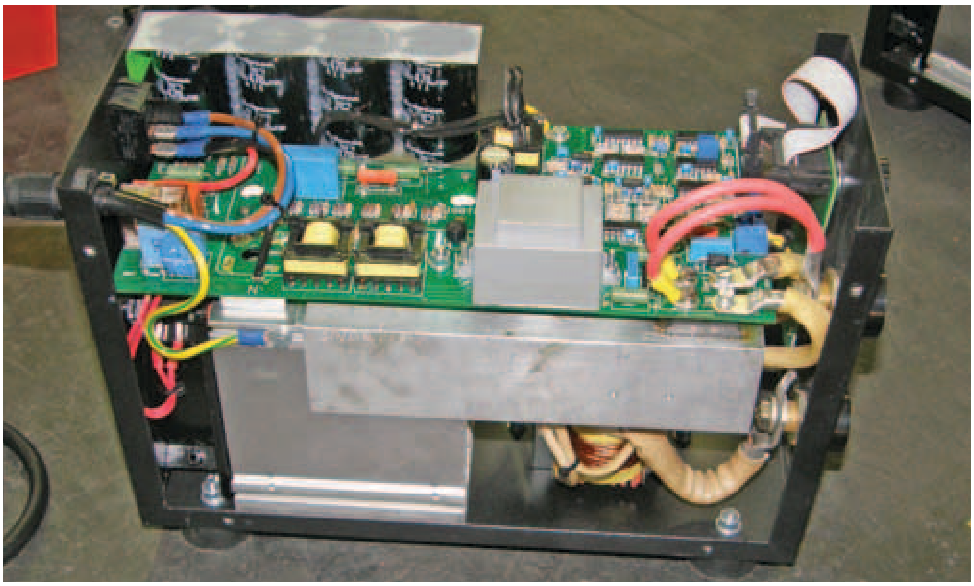
Dr Philip Theron.

Historically, the primary business of Reeflex welding was the manufacture and repair of welding machines for the South African mining industry – mostly 50 Hz oil-cooled AC welding transformers. In 1996, however, the company entered into a technology agreement with Dr Philip Theron, who had recently patented a welding inverter. "Reeflex contacted me and asked if I could make a 300 A oil-cooled welding inverter suitable for the 525 V three-phase input supply, common on the mines. That is where everything you see here today started," Theron tells *African Fusion*.

Since then, the transformer side of Reeflex's manufacturing operations has became smaller and has recently been sold, "and today, the company only makes inverters," he adds. "The oil-cooled transformers were difficult to work on and a nightmare to repair." He points towards the gantry crane in the far corner of the workshop. "That used to operate for nine hours a day when the company was making transformers. Today we use it for unloading consumables."

Theron takes us on a tour of his factory: "This is where all Reeflex inverter welders are made, " he says. The range goes from a soon to be launched 700 A machine for arc-air gouging to a very lightweight and compact 140 A welder for TIG and stick welding, weighing only 6,0 kg. "We are also about to launch our own wire feeder," he adds, pointing to a row of feeders being assembled. "You are looking at the first 10 on the production line."

Further along he shows us the smallest machine, the 140, 150 or 160 amp units for single phase operation. "This is a very simple little machine. This is the power pack with its aluminium heat sink, which holds all of the power semiconductors – the input rectifier, the electronic switching devices, and the output diodes," he explains. "For the switching devices, we only use Insulated Gate Bipolar Transistors (IGBTs), which are internally insulated from the bases that they are mounted on. The heat sink is earthed so that the high voltage is contained within the pack that comes from the factory.



The smallest (6,0 kg) Reeflex machine, the 140, 150 or 160 A units for single phase operation.

"All we need to do is to mount them properly to ensure good thermal contact with the heat sink. This makes the new devices very safe," says Theron. "While these machines are running, you can touch the heat sink, because it is earthed. Some machines available today use cheaper IGBTs or MOSFETs, which are not insulated, so the heat sink is at potential, making these units much more dangerous."

He moves on again and we see larger machines being assembled. "These are 300 A machines now made for the mines, with a three phase 525 V input. This is a very popular machine for the mines." He points out a 400 A stick/TIG/MIG machine: "This 400 A unit has a very high duty cycle. You can weld with it all day long."

Up the stairs we see transformers being manufactured. "All our transformers are also manufactured here," says Theron. "The higher frequency used for inverters enables the size of the transformer to be reduced significantly and much less copper to be used," he explains. "These inverters are running at more than 20 kHz, ie the frequency is 400 times higher than a traditional 50 Hz transformer. These transformers you see being made are for the 300 A units. They have a centre tap and two ends, with three turns on each side. Each can cope with 5,0 kW, so we need two for our 300 A welding machines to give us 10 kW of output." Each transformer is 6,5 by 6.5 by 10 cm, ie smaller than 420 cm^3.

"The smaller machines run at 33 kHz, not really to make the transformer smaller, but to make them cheaper,

Inverter welding transformers are much smaller and cheaper than the traditional 50 Hz welding transformers. These being manufactured at Reeflex have only three turns on each side and each can cope with 5,0 kW of output welding power.

A 400 A stick/TIG inverter welding machine being assembled by Vincent Barns at Reeflex Welding in Strydompark.

by using less copper and less ferrite," he adds.

Theron takes us into the test area, where each machine is thoroughly inspected and then tested. "Each one is connected to an oscilloscope and power supplies, and a few preset potentiometers are calibrated – to make sure that they run at the correct frequency and output current," Theron explains.

Back in the office, he explains how inverters work: "All inverters use a 50 Hz AC input, either single phase or three phase. The AC supply then goes through a rectifier and onto a capacitor bank to give a DC link voltage. If you rectify 380 V three phase, you get a 540 V DC-bus, 525 V three phase gives you 740 V DC, while the single phase 240 V input rectifies to 310 V DC."

He then explains how the high frequency switching works: "We use four IGBTs in an H-bridge to 'gate' the current, both on and off. You switch two diagonally opposite IGBTs at the same time so that the positive and the negative DC link voltage is switched across the load. Then you switch off these IGBTs and you switch on the pair on the opposite diagonal, which switches the DC link voltage in the opposite direction across the load. By doing this at high frequency, you create a square wave AC signal."

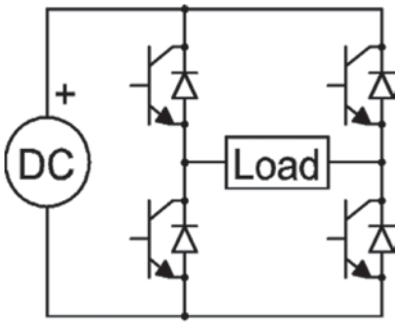
The output power is controlled using pulse width modulation (PWM): "All of the leading edges are fired at exactly the same time but, by controlling the width of the on-pulse, you control the output power. If you switch on and off almost immediately, then you will have a very low power output. If you leave the IGBTs on for a longer percentage of the pulse time, then the output will be higher," he explains.

For a welding inverter, this high frequency AC signal is then passed through the small output transformer and an output rectifier circuit, which converts it into high current, low voltage DC welding power. "This then goes directly into the welding arc. We don't even need an output choke," Theron says.

By switching at above 20 kHz, you can make changes to the current 40 000 times per second, compared to a 50 Hz machine that can only be changed 100 times per second. This makes the machine much more accurate and controllable to suit the continuously changing circumstances of the welding arc.

We ask about reliability: "Early inverters used thyristors, which can be turned on in the forward half cycle but can only be turned off by reverse biasing the device. This can only be achieved by using a naturally resonant circuit, which is more difficult to control and you can only make changes during the positive half cycle. Then came the use of MOSFETs (metal oxide semiconductor field effect transistors). These can be switched on and off so they don't rely on a resonant circuit but they are not very robust. Any voltage or current spike will destroy a MOSFET," he tells *African Fusion*.

IGBTs, he says, have now led to a new generation of much more reliable inverters. "Every year, manufacturers come out with newer and better IGBTs – more reliable, faster switching and with lower losses. The switching devices in the early inverters were the weakest link. With IGBT, that is no longer the case. We have machines that have been running for 10 years or more. There are about 24 000 Reeflex inverters currently being used mainly in southern Africa, and they have proved to be very robust. You can't break our machines unless you abuse them," he claims.



A simple circuit diagram of an H-bridge inverter.

"I also have a patent on overload control for the IGBTs in conjunction with the HF-transformer. I use a safety sensing system, which is much faster than other systems." He explains how this works: "Conventionally, you protect IGBTs by looking at the output current and adjusting the duty cycle using pulse width modulation. I directly measure the current passing through the IGBTs in both directions, which allows any IGBT to be switched off within one microsecond of an over current detection – in either direction."

"On our 400 A CC/CV machine, we were manufacturing for about four years before we lost the first IGBT," claims Theron, "and, of the 1 000-odd 400 amp stick welding machines out in the field with Fuji IGBTs, I have never lost one," he concludes.