RF AMPLIFIER FOR NEXT GENERATION LIGHT SOURCES*

J. Przybyla#, E. Radcliffe†, e2v technologies limited, Chelmsford, Essex, United Kingdom

Abstract

This paper describes the design concepts and development issues around generating a compact 16kW 1.3GHz RF amplifier for use in the next generation of light sources. These amplifiers need to be operated for extended periods to maximise use of the facility and so high reliability and availability are of key importance. Equally important are the capabilities to have extensive self-monitoring and fault prediction, autonomous operation, low heat dissipation to air, and easy maintenance. The design and development of such an RF amplifier based on the latest e2v technologies 1.3GHz inductive output tube (IOT) will be described. The RF amplifier equipment makes extensive use of COTS (commercial off the shelf) components and industry collaborations to produce an amplifier that meets all the requirements yet can be manufactured and operated in a most cost effective manner. Prototype equipment will be on show at EPAC'06.

INTRODUCTION

This paper will detail the construction of the new e2v technologies compact IOT amplifier, which is currently in an advanced stage of development. The design of the amplifier has made extensive use of all the advanced CAD capability available to the engineers at e2v technologies. This paper will describe how the use of modular construction based around COTS components and how industry collaborations, have produced an innovative new amplifier design capable of meeting the needs of both science and industry.

The amplifier considered here is targeted at the 4th Generation Light Sources, of which several are being developed throughout the world. This particular amplifier is designed around the new e2v technologies compact IOT with a nominal RF output power rating of 16kW at 1.3GHz. A brief specification is contained in Table 1.

Although this amplifier is of modest power, the system design has the flexibility to accept tubes of other power levels and frequencies with only minor design changes.

DESIGN AIMS

- High reliability - minimum down-time
- High efficiency – 3 phase mains to RF power out
- Low Cost – system cost, and cost of installation
- Compact size – relative to conventional technology
- Low cost of ownership
- Low Environmental impact – temperature, radiation, etc

Table 1: Typical Specification for RF Amplifier

Parameter	Requirement
Frequency	1.3GHz
RF Input Power	0dBm
RF Power	16 kW
Bandwidth	5MHz
Mains Supply	3-phase
Power Factor	Unity
HV PSU Efficiency	>90%, typical 95%
HV PSU Ripple	<1%, typical 0.1%
Availability	>99%
Max discharge energy	<15 J
RF Output Phase Stability	<±0.5º
Dimensions	Depth: 1m Width: 1.6m Height: 2m

AMPLIFIER OPERATIONAL REQUIREMENTS

Operation of the amplifier requires that coolants, heater power and focussing fields are applied to the vacuum tube in the correct sequence and maintained within tight limits. Having achieved the correct operating environment, the high voltage and input RF drive can be applied to the tube when operator and site safety have been assured. This is achieved by using a MACE (Measure Act Control Environment) control system to continually monitor the system parameters such as coolant flows and temperatures heater, focus and HT voltages and currents. Variation in parameters are logged and used to generate trends data that can be used to assess maintenance periods.

AMPLIFIER DESIGN AND CONSTRUCTION

The amplifier is contained within a standard two-bay, EMC shielded, 19-inch rack unit. Fig. 3 and Fig. 4 show the front and rear views of the amplifier generated from the 3D engineering model generated for the design of the amplifier system.

The mechanical design of the amplifier was achieved by using Pro/ENGINEER™, generating the 3D models and linking into ANSYS™ and Icepak™ modelling

*Work supported by e2v technologies limited
#jan.przybyla@e2v.com
†ed.radcliffe@e2v.com

software as required to verify mechanical, thermal and electrical parameters of the design.

Reliability and availability have been prime drivers in the design of the amplifier. However, if system failures will occur, the use of LRUs (Line Replaceable Units) and a sophisticated control system (MACE) ensures that the faulty system can be identified and replaced within 2 hours.

Fig. 3 to Fig. 6 shows some of the features of the system design.

KEY PARTNERSHIPS AND COMPONENTS

The amplifier contains several subsystems most of which are constructed from and contain COTS components. The specialist nature of this system required that two of the major subsystems be specific to this range of amplifiers:

- The high voltage power supply
- The control and monitoring system

High Voltage Power Supply

Converteam and HiTek Power are developing the two sub-systems for the high voltage power supply:

- Converteam are supplying an active power factor control unit that deals with all existing power quality and EMC emission regulations and converts the 3-phase mains into a stable dc voltage of ~800V.
- HiTek Power are supplying the high voltage DC-to-DC converter, which utilises three phase-shifted H-bridges, switched at ~30kHz. The resulting output ripple frequency of 180kHz reduces the size of the output filter inductor and capacitor, ensuring crowbar less operation. In the event of a tube arc, the PSU will deliver <15J into the arc before the PSU is switched off or inhibited.

Control System

The control system uses National Instruments Compact FieldPoint™ Programmable Automation Controller (PAC) running embedded LabVIEW™ Real-Time software. A major feature of the amplifier development is the control and monitoring system. The basic capabilities of the MACE system are shown in Fig. 1 and Fig. 2. The MACE system has the flexibility to use standard building blocks, which are easily adapted and extended to meet all the future control requirements.

TBG Solutions (one of National Instruments Certified Alliance Partners) have been selected to take the concept from system flowchart through to the hardware, supplying the Control System sub-assembly as a fully tested LRU.

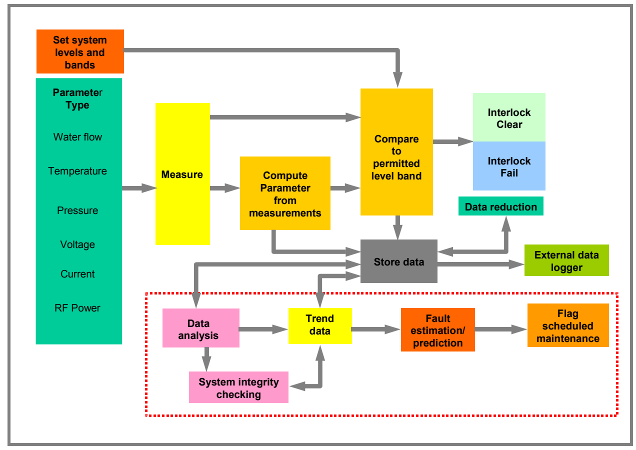

Figure 1: IOT Amplifier Basic Control Scheme

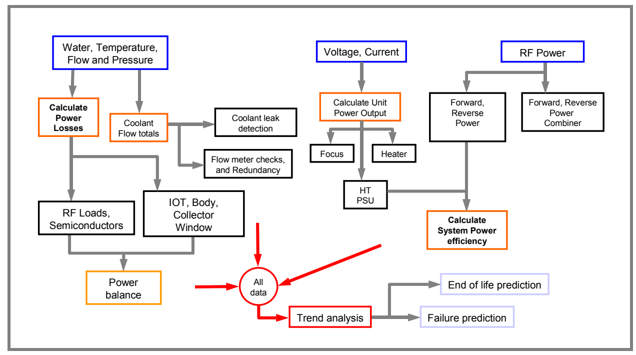

Figure 2: Measurements and System Calculations

CLOSING STATEMENT

The amplifier is now in an advanced state of design and construction. Testing of a prototype unit at Daresbury Laboratory is scheduled for December 2006. A full size prototype model will be exhibited at EPAC'06. Assembly of the prototype unit was completed with minimal effort hence demonstrating the success of the original design concept.

ACKNOWLEDGEMENTS

The authors thank the support of e2v technologies in the development of this programme and assistance from the participating organisations. The authors thank R. Rush for help in proof reading the final drafts and K. Witt for the artwork.

REFERENCES

[1] J S Przybyla, "RFS-TN0019 Amplifier system design concept," unpublished, January 2005.

[2] BS IEC 61000-3-4, "Electromagnetic compatibility (EMC) - part 3-4: limits - limitation of emission of harmonic currents in low-voltage power supply systems," 1998.

Figure 3: Front View Extracted from the Engineering Model.

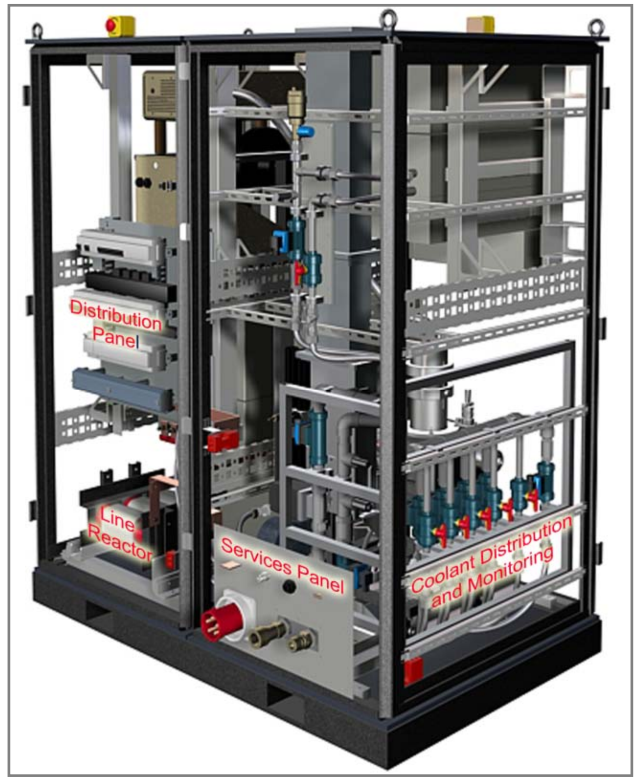

Figure 4: Rear View Extracted from the Engineering Model.

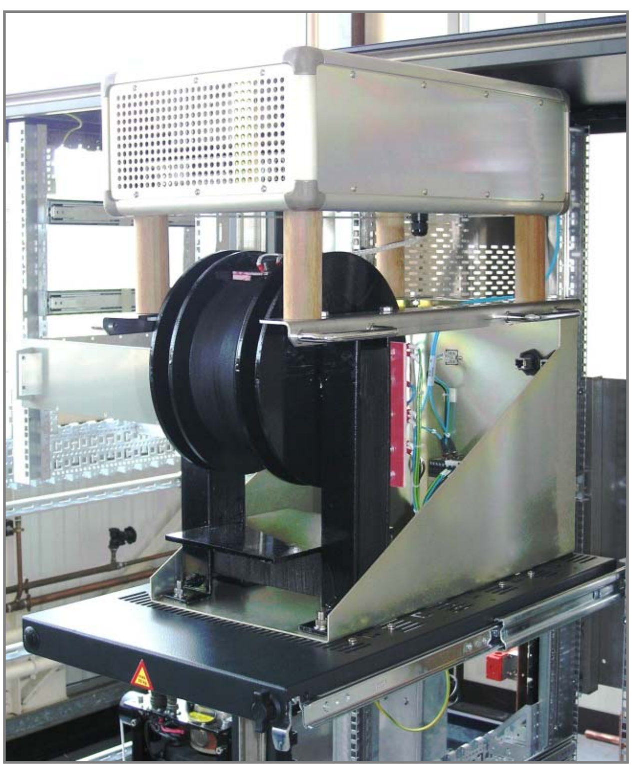

Figure 5: Photograph of the Cathode Deck.

Figure 6: Photograph of Cabinet During the Assembly Stage.