Design and Development of FPGA Softcore Processor Based TCP/IP Module for Real Time Computers in Nuclear Power Plants

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Abstract

An VME(Virtual Module Europa) bus based Real Time Computer’s (RTC’s) are being developed for Prototype Fast Breeder Reactor (PFBR) which is in an advanced stage of construction at Kalpakkam, where the RTC’s have to communicate to the central process computer on the data collected from the field instrument and receive data from the central process computer. A Distributed Digital Control System (DDSC) architecture has been designed for this communication which is based on Transfer Communication Protocol/Internet Protocol (TCP/IP) over Ethernet. Currently the RTC’s uses “Wiznet Module”, a bought out chip which implements the TCP/IP stack in hardware. This project concentrates on the design and development of Field Programmable Gate Array (FPGA) based TCP/IP module that runs on Microblaze, a 32-bit softcore processor, to take care of the communication as that of Wiznet module. Advantage of switching over to FPGA based system are its reconfigurability, desired number of sockets, and the design is stable even if the FPGA’s get obsolete.

Index Terms—VME bus, Real Time Computer’s, Distributed Digital Control Systems, TCP/IP, Wiznet, Microblaze.

1. Introduction

The Prototype Fast Breeder Reactor (PFBR) is a 500MWe, sodium cooled, pool type, mixed oxide fuelled reactor having two secondary loops and is in the advanced stage of construction at Kalpakkam, India. It is first of its kind being built in India using Sodium as coolant and fast neutrons to sustain the nuclear reaction in commercial scale. Instrumentation & Control (I&C) systems are heart of any plant and they play vital role for safe and smooth plant operation. The information received from the field instruments are to be provided effectively and user friendly to the operator, so that he/she can make correct decisions and implement them in the shortest time possible. In nuclear power plants, I&C systems are used for protection, control, supervision and monitoring. The I&C systems of PFBR are categorized as safety critical, safety related and non nuclear safety systems (NNSs). Safety critical systems play a principal role in achievement of nuclear power plant safety. Safety related systems play a complementary role in achievement of nuclear power plant safety. Non nuclear safety systems play auxiliary or indirect role in achievement of nuclear power plant safety. The proper operation of safety related systems may avoid the need to initiate safety actions by safety critical system. In PFBR, the VME based Real Time Computer systems are deployed at different locations in the plant thereby achieving both functional and geographical distribution.

The I&C architecture is a three layered Distributed Digital control Systems. The bottom layer has field instruments which are controlled by the Local Control Centers (LCC). The middle layer form the LCCs, where the RTCs are placed at different locations. The top layer has the process computers and the display stations in the control room which do the supervisory control by sending the control parameters in configuration data as prescribed by the operator.
Around 80 RTC systems are located at 11 local control centers of PFBR. Figure-1 shows the simplified architecture of Distributed Real Time Computers wherein RTC systems are placed at local control centers namely LCC1 and LCC2. In figure-1 ES1 refers to safety critical systems, ES2 refers to safety related systems and ES3 refers to non-nuclear safety systems. Each RTC system is connected to dual redundant switches present at LCC via category 5 UTP cable. Distance between LCCs and Control Room is considerably large. Hence fiber optic cables are used to connect switches across buildings. Safety critical and safety related core switches are connected to NNS core switches which are also termed as ‘Plant Backbone’. All plant parameters can be monitored through NNS core switches. Process computers (PC) which are server class machines also connected to NNS core switches wherein all plant parameters are stored for historical data logging. Many operator display stations are connected to process computer where all plant parameters can be viewed. Dedicated display stations are connected to respective core switches in order to monitor the plant parameters in case of non-availability of PC.

II. Current Design
In current design, the RTCs uses Wiznet module, which is a hardcore processor, that takes care of TCP/IP communications.

III. Proposed Design
The current design has certain limitations such as obsoleteness, limited number of sockets (only four), unknown internal design. To overcome the limitations in the existing system, it has been proposed to design a FPGA based TCP/IP module, which takes care of the communication part, just similar to that of the Wiznet module. Some of the advantages in proposed design are FPGA reconfigurability, more number of sockets as desired, internal design is known, design is stable even if the FGPA gets obsolete.
I. Design and Network Module

Fig. 4 Schematic overview of proposed work done using Altium designer

Fig. 5 FPGA 10/100 Ethernet/PHY connection drawn using Altium designer

Fig. 6 FPGA Bank0 connection drawn using Altium designer

Fig. 7 FPGA Bank1 connection drawn using Altium designer
IV. Result and Discussion

Wiznet module (for TCP/IP communication) was used in the existing designs, which is becoming obsolete and its limitation of only four sockets makes us plan for its replacement with softcore EMAC controllers also downloaded to FPGA and a software TCP/IP stack implemented over an operating system ported to run on the softcore processor. Micrium provides such open source operating system and TCP/IP stacks for real time embedded applications. Experiments have been done successfully on a Xilinx SP605 development board and the design of universal RTU with RTOS has been done.
V. Conclusion
Once the proposed design is completed, in the manufactured product the TCP/IP stack (LWIP stack) is modified which is ported over Xilinx kernel running on the Microblaze. The whole setup is ported over the Xilinx Spartan FPGA and the full fledged testing for the capabilities of the new communication module will be done.

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VII. References