Objective
Implementation of a robust and resilient Ethernet network to support standard protection, control and automation systems compliant to IEC 61850 for MEPSO’s 220/110/35kV “Skopje 1” substation.

Solution
Redundant Ethernet network consisting of two independent rings of RSG2100 switches and RS416 serial servers connected to RX1500 routers providing solid communications infrastructure that ensures secure and fast operation of IEC 61850 protection, automation and control system.

Company Overview
MEPSO is a state-owned utility and the electricity transmission system operator of Macedonia. Their core business is bulk electricity transmission via high voltage networks. They are responsible for reliable and continuous electricity supply to selected large industrial consumers and to the medium voltage distribution grid, which is operated by EVN Macedonia. MEPSO manages and dispatches the electricity transport throughout Macedonia, as well as takes care of controlling and balancing the power system. MEPSO owns 2.096km of high voltage transmission lines, 50 substations of voltage levels ranging from 110kV up to 400kV and owns 148 power transformers accounting for a total of 6.417 MVA of installed power transformation capacity.

Customer Requirements
MEPSO wanted a substation automation design capable of integrating protection, measurement, local and remote SCADA control, status monitoring, automatic control functions, interlocking, alarms and event logging into a single system.

KONČAR-Electrical Industries Inc. (KONČAR-Group) is one of the biggest industrial companies in Croatia. Their main focus is in providing solutions for power generation, transmission and distribution as well electric traction and industry. KONČAR-Group’s Plant and Electric Traction Engineering division (KONČAR-KET), designs and builds complex electric plants and turn-key installations for power generation, transmission and distribution, renewable energy, transportation, oil and gas, water, chemical and other industries. The list of references includes hundreds of greenfield and refurbishment substation projects, power plants and industrial plants in more than 80 countries across Europe, Africa and Asia. KONČAR-KET manufactures its own protection, control and automation solutions as well as integrates equipment from third-party vendors.
ment is expected to meet or exceed in terms of temperature, humidity, EMI radiation and immunity were also specified. Factors that would increase the network's reliability in terms of MTBF and MTTR were considered essential. As such, equipment with dual power supplies, self-monitoring capabilities and extended warranties were to be given preference. With regards to availability, it was deemed essential that the substation automation network is constantly available to facilitate protection tripping, interlocking and other critical functions. The network was also expected to meet design principles that apply a minimum of n-1 redundancy criteria.

From a performance perspective of an IEC 61850 system, the communication network was expected to meet and, if possible, exceed the performance of a conventional hard-wired system. High speed generic object-oriented substation event (GOOSE) messaging, as defined in the IEC 61850-8-1 standard, needed to be available under all operating conditions. The architecture of the network was to provide for flexibility, availability and scalability thereby allowing for future growth and modification without impact to system operations.

The substation network was expected to enable sharing of multiple services on a common communications infrastructure. This included substation automation, video surveillance, SCADA, access control and cyber security.

Application and Implementation

The protection and control system for "Skopje 1" substation is based on IEC 61850 technology and was refined by KONČAR-KET while delivering projects worldwide. The system consists of PROZA NET SCADA software, General Electric relays and RUGGEDCOM networking equipment.

PROZA NET is a modular and multi-user system for control, monitoring and management of power system. It features SCADA, EMS, DMS, GMS functionality and real-time analysis of electrical processes. PROZA NET offers wide selection of communications protocols including IEC 61850, IEC 60870 series, TASE.2/ICCP, DNP3 and legacy protocols such as LON. It features a powerful graphical user interface and HMI (human machine interface) that is shown on Figure 1.

The substation network design for "Skopje 1" substation is comprised of two independent switched Ethernet networks, both based on ring topology as shown in Figure 2. The redundant RSG2100 switches and RS416 serial servers, located in the substation control room, are connected to a router that serves as the main access point to the substation from MEPSO's corporate network. This network topology was selected because of its security, flexibility and high performance. Such design is scalable and allows for future extensions without impacting the system. The decision of using separate duplicated LANs was motivated by the desire of having two independent networks at "Skopje 1", one for substation control system and the other for substation monitoring system. The intention was to come up with a network design independent from IED vendors and that would be modular and scalable.

Parallel Redundancy Protocol (PRP), specified in IEC 62439, was considered as a natural choice for duplicated network topology. However, because this technology is not yet mature, it was decided that each protection relay in the substation will be accessed via two independent IP addresses on two separate LAN networks. This has been achieved by enabling all relays with a second independent communications channel via serial port and by connecting the IEDs to Ethernet network via RUGGEDCOM RS416 serial servers. Currently IEC 61850 does not imply a particular redundancy method or network topology however the upcoming IEC 61850-90-4 Network Engineering Guideline will provide practical recommendations on this topic.

A major design requirement of the substation network was to allow for flexibility without impacting the real-time performance requirements of the network. The concern was that network congestion could cause delays in the delivery of critical IEC 61850 GOOSE messages. This was addressed by fully leveraging Ethernet's prioritization scheme (as defined in IEEE 802.1p) and with traffic isolation mechanism by means of VLANs (as defined by IEEE 802.1Q). For further optimization of the network unique group destination MAC addresses are going to be used for GOOSE applications.

All protection relays, as well as RUGGEDCOM switches and routers, in "Skopje 1" substation will be using redundant power supplies for higher system availability. Rapid spanning tree protocol (RSTP) will be used for network redundancy and automatic failover in case of network failures. Should a highly unlikely catastrophic condition arise, where the substation network is rendered unavailable, the protection will still operate because all connections with the primary equipment (instrument transformer inputs and trip coil outputs) are hardwired directly to the protection IEDs.

"We have chosen RUGGEDCOM because, as a turn-key solution provider, we are responsible for delivering a reliable and secure automation system. We have been using RUGGEDCOM equipment for several years and we are confident these devices make a rock-solid communications network. We also value the RUGGEDCOM 5 years warranty", says Goran Leci, Head of Secondary Equipment Division at KONČAR-KET.
RUGGEDCOM RX1500 Key Features
- Modular hot-swappable Layer 3 switch and router
- Integrated Router/Firewall/VPN/IPSec/NAT
- Layer 3 protocols allowing network segmentation into multiple IP domains
- Dual redundant power supplies

RUGGEDCOM RSG2100 Key Features
- Enhanced rapid spanning tree protocol (eRSTP™) for ultra fast network fault recovery (<5ms)
- Robust design with -40°C to +85°C operating temperature range
- VLANs for segregation of a physical network into separate logical networks
- IEEE 802.1p class of service to minimize latency and jitter of GOOSE messages

Benefits
- Modular high density serial server, up to 16 serial and 4 Fast Ethernet ports
- Support for Modbus TCP, DNP3 and any serial protocol via Raw Socket mode
- 19 inch rack form factor and dual redundant power supplies
- Rugged Rated for reliability in harsh environments

Customer Benefits
- Utility grade network exceeding the IEC 61850-3 standards with dual independent fiber optic rings
- Scalable and flexible network design allowing for non-intrusive future expansions
- Future-proof topology enabling future migration to upcoming standards such as IEC 62439 Parallel Redundancy Protocol (PRP) with minimal operational impact
- Network segregation, traffic prioritization and enhanced security thanks to the use of VLAN technology
- Multiservice network without compromising the operational requirements of the substation automation systems