Variable speed drives (left) and custom built mechanical services switchboard (right) are part of a trigeneration system in Australia.

BACnet® & Trigeneration

By Tim Davis

Canberra International Airport in the Australian capital city of Canberra has adopted green building principles to minimize carbon emissions. As part of this commitment, a trigeneration system was installed to provide power for four office buildings that are part of the airport complex's Majura Office Park.

The central services building (CSB) at the office park is a two-level structure (basement and ground levels) over approximately 1000 m^2 (10,764 ft^2) of building area, predominantly below ground. The building houses the mechanical services (heating/cooling and trigeneration) that serve the office park buildings (approximately 40 000 m^2 [430,557 ft^2] of net leasable area at completion).

The building houses Australia's largest trigeneration plant, consisting of a 1,200 kW (341 ton) gas generator and absorption chiller. Switch rooms to service the adjoining substation are also housed within the structure.

The CSB has been designed to a Five Star Australian Building Greenhouse Rating. The contractor for the supply and installation of mechanical electrical services and building management service (BMS) controls completed the installation in December 2008.

Trigeneration is the production of cooling, heating and power from one fuel input. The CSB uses natural gas, which is the energy source that generates electricity. Excess heat (fugitive emissions) that otherwise would have been lost during production of electricity is used to heat and cool the buildings using state-of-the-art absorption chillers. The hot water that is generated is available for use as domestic hot water. The trigeneration plant also has the potential to produce surplus power that can be sold back to the grid as greener electricity.

The Canberra region has a summer of high temperatures and a winter of freezing temperatures. This environment is not entirely suited to cogeneration because the high summer temperatures increases the payback period for a cogeneration plant. In a climate of extended periods of colder temperatures, the cogeneration could be used more often, increasing the efficiency of the plant. Trigeneration, however, with its increased efficiency in heating and cooling has the potential to be useful in the Canberra region (see sidebar, "Trigeneration Basics").

This project was a collaboration of the consulting engineer, client, mechanical contractor, and BMS/electrical services contractor. The task was to design and construct the trigeneration system, us-

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Trigeneration Basics

Cogeneration uses a generator or other heat engine to produce electricity to power a building. Any excess heat from the generator is used to heat the building when required. Heat from the generator only can be used when the building requires heating, so cogeneration is suitable to cold climates. Trigeneration uses a generator and an absorption chiller, which has the ability to convert waste heat from the generator into cooling energy. The efficiency of a trigeneration plant is potentially much higher than a traditional HVAC plant and cogeneration plant.

Trigeneration can reduce the impact of external power outages on building power, heating and cooling. This is especially significant for large computer installations where cooling of the system is essential. Transmission costs also are reduced. Trigeneration plants reach overall system efficiencies of 90%. Typical central power plants that use boilers for heating and chillers for cooling and do not recover any waste products are about 33% efficient.

With the installation of the trigeneration system, the complex has lowered the CO_2 emissions by more than 1 million kg per year (1102 ton). This equates to about $163,500 per year saving on energy costs.

A gas-fired generator can potentially save up to 2400 L (634 gallons) of water per hour of operation compared to energy produced from coal.

ing a natural gas-fired generator that produces electricity and heat, and an absorption chiller that uses the waste heat from the electricity generation to chill water. The electricity is used in the Majura Office Park and sold back into the grid; the chilled and heating water is used for heating and cooling in the four office buildings.

The BMS engineering and construction departments worked seamlessly throughout the project and information was shared by the entire team, which enabled a comprehensive and open attitude to achieve commercially viable outcomes and to meet the complex technical design brief. The design process was continually developing during the project, which entailed constant design review of the control system requirements. The design change requirements were filtered down to the project team, including team members who were in Germany and China.

The main communication backbone is a (10/100) MB fiber optic local-area network (LAN) installed between the buildings within the Canberra International Airport Complex (International Terminal Building, Majura Office Park and Brindabella Business Park) using a virtual LAN (VLAN), creating a large BACnet network, with more than 70 BACnet building controller (B-BC) devices communicating using BACnet/Ethernet and connected to the LAN via 10Base-T network ports. BACnet MS/TP (baud rate 76.8 Kbps) is then used to connect to BACnet advanced application controllers (B-AAC) located in the field (such as variable air volume [VAV], fan coil and air-conditioning units, etc.). BACnet MS/TP networks are also used to connect a series of variable-frequency drives (VFD) to these B-BC devices for control and monitoring purposes.

System	Quantity	Third-Party Integration Communications			Native BACnet I/O
		Native BACnet	Modbus	M-Bus	
Chillers	4		•		•
Cooling Towers	3				•
Boilers	3				•
Air-Handling Units	11				•
Fans	23				•
Pumps	42				•
VAV Boxes	84				•
Fan Coil Units	15				•
Pump VFDs	82	•			
Gas Flow Meters	4				•
Magnetic Flow Meters	11				•
Thermal Energy Meters	71			•	
Gas-Fired Genset	1				•
Electrical Meters	54		•		
MSSB	8				•
UPS	4				•
Total BACnet Objects		820	570	355	4973

Table 1: Systems connected and integrated into the building management system.

Separate M-BUS (baud rate 2400 bps) and MODBUS/RTU (baud rate 9600 bps) LANs are used to monitor a network of thermal energy meters, electrical meters, chillers and generator PLC via an M-BUS gateway and MODBUS-enabled application and system controllers.

A dedicated Web server with a 100 Base-T connection serves the Canberra International Airport Complex. Five local operator workstations (OWS) are also installed within plant rooms and facility offices throughout the airport for service and maintenance. The Web server is configured to automatically send critical alarms via SMS text, as well as e-mail to maintenance staff.

Remote connectivity is provided via high-speed ADSL connection to access the Web server, as well as directly to BACnet controllers via remote UDP/IP (BACnet/IP) connection. This arrangement allows quick access to the site in the event of failure of major equipment.

The total connected I/O of nearly 5,000 points is comprised of approximately 20% native BACnet third-party objects, 20% integration of MODBUS and M-BUS objects via multipurpose controllers with built-in router and gateway functionality. The breakdown of the BMS connected I/O is indicated in *Table 1*.

PERIOD		Chillers	Cooling Towers	Chilled Water Pumps	Condenser Water Pumps	Supplementary Condenser Water Pumps	Heating Hot Water Pumps	Air Handling Unit Fans	Ventilation Fans	Lifts	House Power	Total Electricity
11 LANCASTER PLACE - DETAILED MONTHLY ELECTRICITY TARGETS (kWh)												
Total/Accumulative Reading		205.027	19.3353	10670.9	20647.3	47161.5	1607.06	54351	2305	5344.4	137965	266969
Current Month		116.108	7.39868	35.053	237.744	608.428	607.363	3443	196	190.5	1355.28	6793.87
JANUARY	ACTUAL	0	0	0	0	0	0	0	0	0	0	0
	TARGET	3,994	1,718	2,606	2,232	2,100	813	7,943	531	3,272	3,778	28,995
FEBRUARY	ACTUAL	0	0	0	0	0	0	0	0	0	0	0
	TARGET	5,789	1,965	3,036	2,491	1,891	682	7,566	479	2,955	3,412	30,266
MARCH	ACTUAL	21.1027	53.7764	106.356	186.674	1000.98	1648.63	35571	1303	392.9	105191	145475
	TARGET	950	1,030	1,629	1,553	2,086	964	7,063	531	3,272	3,778	23,656
APRIL	ACTUAL	0.814046	1.05487	122.944	6.62521	293.326	41.4544	5655	257	41.65	8147.71	14567.6
	TARGET	459	681	1,116	930	2,005	938	6,666	513	3,166	3,656	20,128
MAY	ACTUAL	0.847431	1.05487	123.538	3.12835	287.112	131.879	4711	256	47.44	10665.5	16227.5
	TARGET	737	512	945	404	2,098	1,428	8,367	531	3,272	3,778	22,072
JUNE	ACTUAL	98.1432	12.919	10263	20204.3	42772.8	1083.36	4951	292	4670.51	6437.87	90697.9
	TARGET	430	436	656	350	2,016	1,433	7,194	513	3,166	3,656	19,850
JULY	ACTUAL	0	0	0	0	0	0	0	0	0	0	0
	TARGET	417	460	635	388	2,093	1,620	7,888	531	3,272	3,778	21,082
AUGUST	ACTUAL	0	0	0	0	0	0	0	0	0	0	0
	TARGET	559	486	893	402	2,098	1,489	8,310	531	3,272	3,778	21,818
SEPTEMBER	ACTUAL	0	196	0	0	0	0	0	0	0	0	0
	TARGET	589	459	889	351	2,017	1,209	7,314	513	3,166	3,656	20,163
OCTOBER	ACTUAL	0	0	0	0	0	0	0	0	0	0	0
	TARGET	749	790	1,309	1,190	2,093	1,099	8,130	531	3,272	3,778	23,021
NOVEMBER	ACTUAL	0	0	0	0	0	0	0	0	0	0	0
	TARGET	2,058	1,268	2,011	1,824	2,029	948	8,236	513	3,166	3,656	25,709
DECEMBER	ACTUAL	0	0	0	0	0	0	0	0	0	0	0
	TARGET	1,913	1,255	1,808	1,641	2,053	731	7,180	531	3,272	3,778	24,162
ANNUAL TOTAL	ACTUAL	205.027	19.3353	10670.9	20647.3	47161.5	1607.06	54351	2305	5344.4	137965	266969
	TARGET	18,644	11,060	17,613	13,756	24,587	13,352	92,657	6,248	38,523	44,482	280,922

Figure 1: Building management system report of electricity consumption versus targets.

The field controllers are conveniently located within an integrated section of the local switchboards. The CSB has four chilled-water chillers, one magnetic bearing centrifugal chiller (CH-1) of 600 kW (170 ton) nominal capacity, one screw chiller (CH-2) of 1,000 kW (284 ton) nominal capacity, one single compressor centrifugal chiller (CH-3) of 2,500 kW (710 ton) nominal capacity and one absorption chiller of 1,150 kW (327 ton) nominal capacity. Each chiller has a dedicated VFD controlled primary chilled-water pump and a single VFD controlled condenser water pump. The BMS sequences the first three chillers and associated pumps based on load from the four office buildings and sequences the absorption chiller (CH-4) when the trigeneration plant is required as determined by electrical demand.

A Web server serves the Canberra International Airport Complex. The main operator interface consists of more than 500 custom graphics.

Systems monitored and controlled from the Web server include:

- HVAC equipment: chillers, boilers, AHU, fans, VAV, etc.;
- Electrical, gas and water metering: monitors various gas and water meters, as well as electrical submeters for energy analysis and billing, including various power factor correction (PFC) cubicles and surge diverters, as well as various pump alarms;
- Rainwater tanks: monitors water meters and system faults associated with the tanks;
- Black water treatment system: monitors pH level of the sewage water and transmitted information between two pump houses to enable plant processing;
- Lighting: controls various space and car park lighting;
- Fire system: monitors fire alarms of all buildings; and
- Elevator system: monitors all elevator critical alarms.

Energy reporting was a vital component in the selection of the BMS. It was important to optimize the efficiency of the CSB trigeneration plant to take full advantage of the sale of surplus energy back to the grid, to maintain the AGBR rating and provide accurate tenant submetering and energy invoicing for after-hours use. The BACnet Web server allowed the easy creation of more than 50 custom reports using ASP (Active Server Page) scripting, providing easy to read operator tables, bar and pie charts. The Web server is also configured to automatically e-mail monthly energy reports to energy consultants for the purpose of billing and/or performance analysis. *Figure 1* is an example of the summary reports on energy use for one of the four office buildings within the complex.

Because of the critical and economic importance, the entire BMS has an uninterruptible power supply.

In conjunction with his own internal quality policies, the BMS contractor incorporated the recently released "Energy Efficiency in Government Operations (EEGO) Policy." This policy is intended to "improve energy efficiency, and consequently reduce costs and environmental impact of government operations." The EEGO policy includes a legal and management framework known as the "Green Lease Schedule" under which government departments and building owners are required to identify, monitor, and report their energy consumption with an aim of reaching a 4.5 star Australian Building Greenhouse Rating.

The BMS contractor's service and energy department ensure that the requirements and intent of the EEGO policy are met and the quality of the BMS are maintained at the CSB by:

- Creating a single point of management to coordinate a holistic and practical approach to energy efficiency;
- Chair and coordinate the building management committee;
- Produce energy management plans and reports;
- Collect and store information, drawings and data;
- Undertake and set targets for energy and ABGR audits;
- Identify potential energy efficiency improvements and monitor their effectiveness;
- Act as an expert to identify and report on issues, which may impact the achievement of the targets; and
- Implement energy efficiency improvements using the BACnet BMS.

The new $288 million Canberra International Airport expansion is using the BACnet building management system to ensure the same level of interoperability as achieved at the Majura Office Park.●