Conventional Thermal Generation

KEDVALE CONSULTANTS DIDCOT A OPEN CYCLE GAS TURBINE UTILISATION.

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INTRODUCTION

Didcot 'A' was a 2000MW Coal fire power station comprising four 500MW units. The power station was designed by the Central Electricity Generating Board Midland Projects Group and was commissioned circa 1970. The station is also furnished with four open cycle gas turbines, each of which is connected to a unit 11kV switchboard.

The station is opted out in respect of the EU large combustion plant directive and is hence scheduled for closure by 2015. Final generation took place in 2013.

The station has four open cycle gas turbines which can generate appreciable income from NGT's STOR contract. Fortunately, the gas turbines are located in a separate generator hall sufficiently remote as to be separate from the wholesale demolition of the for 500MW sets.

Kedvale acting on behalf of ABB Power Generation, were responsible for determining a mechanism for realizing a revised connection topology with minimal capital spend.

Civil Engineering

In order to minimize spend a means of using an adjacent workshop building to accommodate a new 11kV switchboard and associated protection and control panels together with metering and DC standby systems was realized. A steel portal frame building intended to be erected within the existing building was conceived and Kedvale worked in close liaison with the Civil Engineering Consultant to produce an effective solution.

Protection and Control

The two Didcot A station transformers each rated at 55MVA OFAF are supplied from Drayton 132kV substation some 6 miles distant from the generation site. One circuit is carried to the site on a single circuit tower line the second circuit is under grounded.

There are four gas turbines each rated at 25MW and generating at 11kV. These were Protected by a range of obsolete attracted armature induction pattern relays located in cabinets within the A station 11kV switchrooms.

Kedvale conceived new protection panels for two 132kV feeder circuits, two station transformers including tap change control facilities, four gas turbines, Two auxiliary 11/0.4kV transformers, and bus bar protection of the 11kV switchboard.

132kV Line Protection

The 132kV switchgear at Drayton had been replaced some 10 years previously with 5000MVA fault capacity circuit breakers, at this time the underground circuit had been provided with a Solkor R scheme and isolated to 15kV. The second feeder (OHL) had been furnished with a distance relay scheme. Control of the 132kV Drayton switchgear was effected by means of GE outstation connected via modem across a pilot pair. This scheme being relatively modern was retained and transferred to a new relay panel.

Generator Protection

Each generator was to be protected by a main and back up protection scheme each of which was wholly independent of the other. The IEDs chosen for this application was the ABB Relion range and in particular the REG670 IED. Neutral end current transformers were retained and matching CTs were specified for the 11kV switchgear. A 250kVA unit transformer intended to supply the gas turbine auxiliary load was directly connected to the alternator terminals and was located in the machines differential zone. An additional Overcurrent and Earth fault IED was utilized to provide closer protection to this transformer.

132/11kV Station Transformers

Two 132/11kV 55MVA OFAF Station transformers were to be used to provide the export power path to the DNO 132kV system. The protection for these transformers was again based on obsolete induction disc attracted armature relay technology. In addition the transformers were equipped with an on-load tap changer.

Kedvale expedited a new protection design based on ENTS-41-15 using modern IEDs and an embedded automatic voltage control scheme based on the line drop compensation principle which could be disabled when generation was connected and the station operator could remotely manipulate the tap change mechanism via SCADA.

Bus Bar Protection

Owing to the relatively high fault level at 11kV (750MVA) it was necessary to employ unit protection throughout the 11kV system. A simple single zone of high impedance bus bar protection was employed to cover each bus section.

Synchronising and Standby Control

A standby control panel was provided to allow control of the 11kV circuit breakers from the protection room and thereby ameliorating the need to for an operator to stand immediately proximate to the switchgear. For indication purposes a mosaic tile mimic diagram was included giving an indication as to the status of the 11kV circuit breakers and attendant earth switches and 132kV disconnector status. In order to prevent an excessive number of circuit breaker open and close control switches a single common switch was designed based around a fortress type interlocking key.

The interlocking key during normal operation was located in a key park located on the standby control panel. A corresponding interlock key switch was fitted to each 11kV circuit breaker. Upon removal of the key from the keypark the system SCADA would receive an input advising that a possible local control was to be executed. When the operator inserted the key into an appropriate lock on one of the 11kV panels and turned it to engage the system, open close control would be passed to the standby control panel and the mimic would indicate the selected circuit breaker. In addition for the generator breakers the incoming and running voltages would be connected to common bus wires so as to energise the common synchronizing equipment also located on the standby control panel.

DC Systems

The new DC system was designed to meet the latest National Grid standards and incorporated dual batteries comprising flooded lead acid cells, a dual charger system and two segregated distribution systems. All 11kV circuit breakers where fitted with dual tripping coils each of which was connected to a wholly separate protection system including DC supply.

System Studies

A detailed system study was undertaken using Digsilent Power Factory software.

- Load Flow
- Cable sizing calculations (including losses calculations) as per IEC 60287
- Fault calculations per IEC 60909 covering all MV and LV systems
- 132 & 11kV switchgear selection calculations

- Voltage fluctuation (including assessment at full power output and during transformer energisation)
- Voltage flicker
- Transient overpower
- Harmonic analysis
- Protection studies and relay settings covering all MV systems
- Electrical Resonance, Switching and Insulation Co¬ordination
- Transient stability and dynamic performance

Of particular concern was the performance of the generator circuit breaker and the prevailing X/R ratio and the ability of the selected switchgear to interrupt current and compliance with. IEEE Standard C37.013.

11kV Switchgear

A nine panel 11kV switchboard comprising:-

- Aux Tx 1 11/0.4kV
- Gas Turbine 1
- Station Transformer 1
- Gas Turbine 2
- Bus Section
- Gas Turbine 4
- Station Transformer 2
- Gas Turbine 4
- Aux Tx 2 11/0.4kV

Was fully specified by Kedvale Consultants which included descriptions of electrical interlocking for fault level control, Boolean logic for gas turbines to determine whether a valid export path was present as a condition precedent to a start attempt, circuit breaker fail handling, X/R ratio and zero crossing asymmetric issues including back tripping for two machine in parallel and a transformer fault. The specification also detailed the data acquisition requirements by means of appropriate protocols over fibre. Facilities for opening and closing NER contactors. Protection schemes to allow any gas turbine to be connected to any transformer as long as no more than two are ever connected.

A voltage selection scheme was also designed and specified so as to facilitate a manual synchronizing station to mitigate against the failure of the automatic synchronizer. This included the provision of incoming and running voltage bus wires, interposing Voltage transformers, a synchroscope , incoming and running voltmeters and a phase angle voltmeter.

Power Cabling

The existing gas turbines were connected to the 11kV unit boards of each of the 500MW thermal units. Under the revised connections topology a new 11kV switchboard would be provided so as to enable the output to be routed to the existing 55MVA station transformers. The original cable designed by Pirelli General utilised a single core 2½ square inch sectored copper conductor with paper insulated lead sheath, mass impregnated non draining design. The conductors were laid in flat formation with a cable diameter between conductors. A single cable of this design was used per phase for each gas turbine and two conductors per phase is used for the station transformer secondary circuit.

Each circuit of the original cable design was contained within a bespoke builders-work trough. The floor of the trough was formed from mass concrete laid on the ground similar to a strip foundation The sides of the trough was formed out of 100mm engineering bricks interspersed with a 225mm square clay air brick every two metres in the walls on both sides.

In order to facilitate connection to the new 11kV switchgear it would be necessary to limit the conductor size to no greater than 800mm2 aluminium conductor. This meant that for each of the original conductors a bifurcating joint was necessary.

The design of the joints took a great deal of design work and Kedvale worked closely with the vendor in order to produce a design which was manageable from the installation point of view and worked firt time in respect of dimensioning and associated mechanical properties.

The new power cables were based on the BS7870-4.10 design with a $70mm^2$ copper wire screen and were placed in new troughs built along the lines of the original civil engineering concept, but this time laid in trefoil between the new 11kV switchgear and the transition joint.

Kedvale project management supervised the isolation and phasing out of the new installation so as to ensure correct phase sequence was maintained.

LVAC Systems

A stand-alone 400V switchboard was provided to receive the power from two 800kVA auxiliary transformers which would supply the local substation services and the residual common services load of the gas Turbine building. The board contained two incomers and a normally open bus section with an automatic change over system (bus section closure) in the event of a loss of one of the incomers.

The gas turbine building received its power originally from the A station's 415V Station Switchboard bus sections 1 and 2 via two feeders. The feeders ran past the new location for the 11kV switchboard and as a consequence, two new feeders were tailed out from the new switchboard and through jointed onto the existing cables.

Auxiliary supplies to the fans and pumps together with the tap changer was replaced from the new switchboard to the existing Marshalling Kiosks.

Earthing System

Each of the two station transformers which had a YNyn0+d vector group was earthed via a liquid neutral earthing resistor of 6.35Ω yielding an 11kV earth fault level of 1000A when supplied from the DNO system.

In the original CEGB design each gas turbine was also earthed via a 6.35Ω LNER and a series 150Hz suppression inductor. The level of earth fault was originally chosen to be so high to allow sufficient grading through the thermal stations 11kV unit auxiliary system. In the new STOR scheme the distribution system is vastly simplified and for this reason the LNERs where replaced with dry type resistors each limiting the gas turbine earth fault level to only 50A. The new NER also featured an integral vacuum contactor so as to remove the earth after the synchronizing breaker is closed.

Owing to the closure of the A station the principal earthing system electrode parks were to become redundant as they were located within the demolition zone.

It was necessary for Kedvale to produce a design for a principal electrode system such that the ensuing touch and step potentials were within safe limits.

Control System

Each of the Gas Turbines' Control System had been replaced with a PLC based control system from Allen Bradley and each GT control suite within the OCGT building was furnished with a Panelview Plus 1500 HMI.

These systems were integrated onto a WAN and a further HMI was to be provided adjacent to the Standby Control cubicle and is to be used in conjunction with the manual synchronizing scheme so as to provide the operator with machine operating status.

IEDs on the protection panels where connected via fibre optic to an optical Ethernet switch, together with the Metering panels and the General Electric D25 system for control of RWE assets at the Drayton 132kV substation.

A soft desk was facilitated for control of the OCGT STOR installation within the Didcot B Power Station control room.

Metering

A full fiscal metering installation was designed and installed commensurate with Code Of Practice 2. The metering panels where supplied by Kenda and housed within the new protection and control room.

Owing to the constraints imposed by the number of cables and their cross sectional area, separate voltage transformers where designed so as to be located in the undercroft of the alternator effecting connection to the live end of the cable sealing arrangement. This was necessary owing to not being able to determine the accuracy class of the existing voltage transformer either from the rating plate or archive material.