Conceptual Design Report for PMEC Facility

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Commercial in Confidence

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1. Introduction

This report describes, at conceptual level, a proposed design for a Test Facility for Wave energy converters for OWET/NNMREC offshore of the State of Oregon. It will have a capacity for four wave devices. The nominal power output of each device may not exceed 1MW at peak. The power generated by the system will be around 1250kW average with variations over the day when four 1MW devices are in place.

The report is not a detailed design and is not intended to be used to purchase any equipment or materials. However, it may be used as an input to engineers for guidance on the detailed design of the electrical and communication systems following US or International standards[1].

Although site selection is not complete for PMEC (at the time of writing) the ideas and concepts outlined in this report are relevant irrespective of the particular site. Once a site selection is made, some aspects will need further consideration to take into account specific site-related requirements.

The scope of this report covers the overall method and approach to development of the PMEC test facilities, the outline description of the electrical infrastructure for the test facilities, including cables; switchgear; electrical measurement; electrical substation concept; grid connection and ancillary equipment. The report also describes in outline the requirements for test devices and the standards associated with them; requirements for power conditioning; requirements for grid connection and details of the measuring devices for both wave and tidal stream resources.

This report also highlights the importance of health and safety in design and operation of the test facilities, including operations and maintenance carried out offshore for the deployment retrieval and any in-situ maintenance of the test equipment and cables.

Some suggestions for further work are also made at the end of the report.

Appendices are included with this report. A list of relevant references is also provided.

[1] The standards published by the International Electrotechnical Commission (IEC) http://www.iec.ch/about/ are recommended to be followed to guide detailed design.

2. Overall Method for Development of Test Facilities

There is a whole sequence of activity that must precede the design and installation of test site facilities and this is addressed in this section.

A number of investigations and surveys are required. It is likely that OWET/NNMREC have already obtained some of this information, in which case gathering it need not be repeated), these include:

- Bathymetry surveys covering areas extending at least 0.5km beyond the proposed offshore berth positions for the best site.
- Tidal current measurements in the area around the tidal berth positions. (Note that these will be addressed in more detail in the appendices).
- Wave climate measurements within a radius of 500m of the wave berth locations using appropriate instrumentation. This is also reviewed in more detail in the appendices.
- A current measuring survey using a boat-mounted instrument in the proposed area of the wave test berths – sites should be chosen such that currents are no more than 0.5-1.0 knots at maximum. (1 knot =0.515 m/sec)
- Survey of potential cable routes with sidescan sonar and diver video survey in the shallows leading up to the proposed cable landing site.
- Sea-bed sampling to identify the biological species in the benthic[2] region.
- Topographic survey onshore the proposed area for the site of the substation, also trial holes to check strength and type of subsoil for civil engineering of plinths and building(s).
- Environmental Impact Assessment (EIA) – in which all stakeholders in the sites are asked for any environmental concerns to be identified. After a scoping study, the means of mitigation of any matters of concern are then developed in the full EIA. Further guidance on this is given in an EMEC document[3].

With the results of the above investigations available, the concepts outlined in this document can be developed for the specific site and passed to the relevant engineering groups for detailed design. The detailed design is intended to produce all documentation required to specify the equipment and materials, estimate bills of quantities from the design drawings and combine with contract and procurement documentation for purchase.

The following engineering activities are required:

- Cable design considerations and cable selection.
- Cable installation specification, including onshore routing, separation calculations etc.
- Outline technical information for planning and other permits/consents.
- Land acquisition/rental.
- Earthworks and civils design.
- Detailing of the substation foundations (including cable ducts and drainage).

[2] This is the seabed surface region where many microscopic life-forms exist
[3] "Guidance for Developers at EMEC Grid Connected Sites: Supporting Environmental Documentation", August 2011

- Detailed investigations for the full EIA.
- Electrical Design for substation including switchgear, protection, metering and earthing.
- Grid Connection design – simulation to investigate grid stability and establish need for controls or storage of power.
- Technical Supporting information for all Purchase Orders (POs) for equipment and materials.

It is not EMEC's expertise to design in detail, so some general guidelines are provided, and indication given where local laws and other requirements will influence detailed design. Some typical examples of design and catalogues for typical equipment are provided with this report – for general guidance only.

3. Description of the Test Facilities

The Test Facilities are intended to constitute four berths in 50m water depth.

A schematic diagram of the Offshore Test Facilities could be as shown in Fig 1 below:

PMEC OREGON OFFSHORE WAVE SITE LAYOUT -

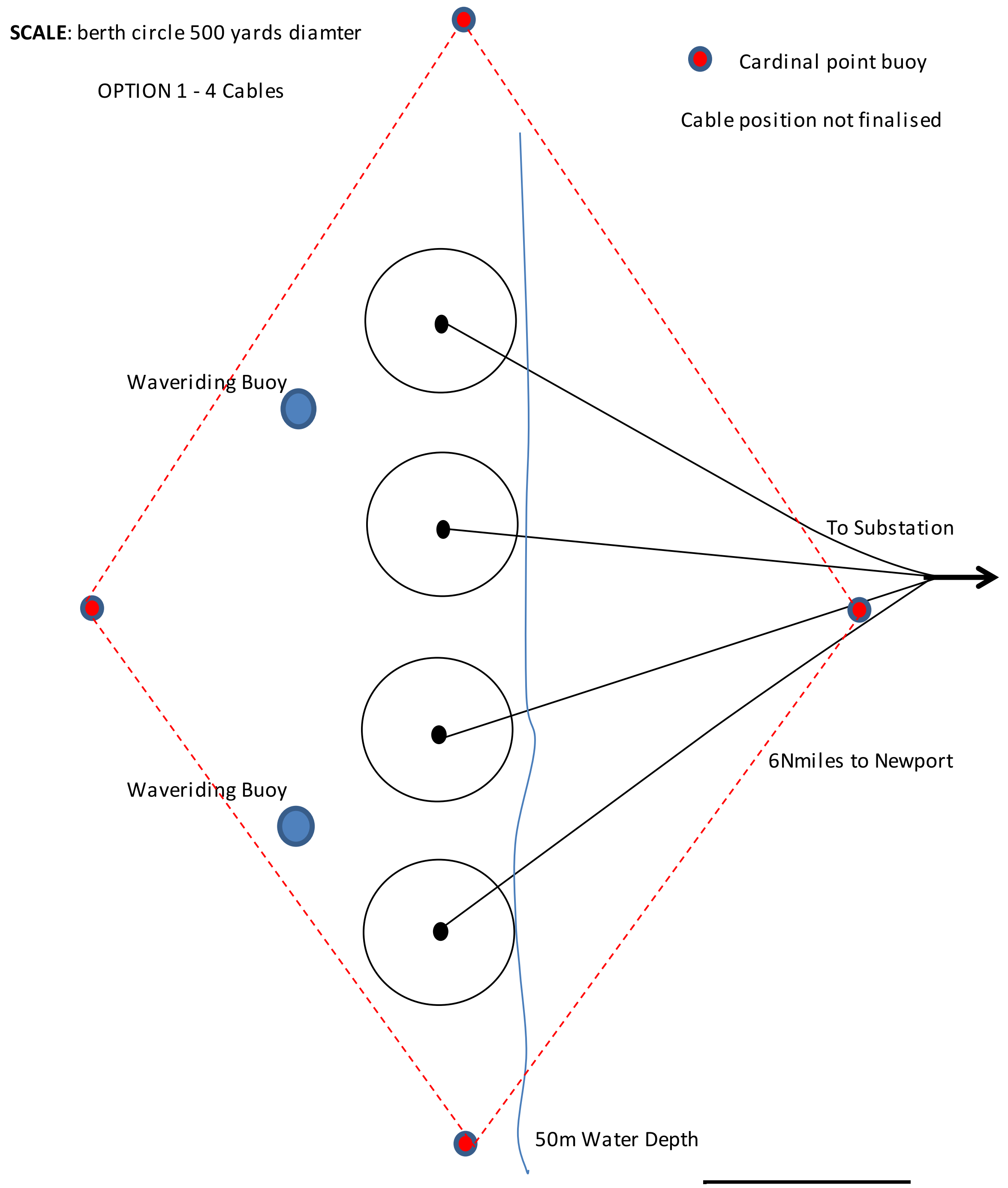

Figure 1 Schematic diagram of offshore layout

The wave energy converters (WECs) berths will be between about 11 km offshore in 50m of water depending on the exact site bathymetry; the distances given are order of magnitude at this stage and must be finalised in detailed design.

A three phase AC current double armoured cable specification is suggested. The cable size will be determined by consideration of voltage levels that best suit the cable lengths to the WECs sites. It is proposed that similar sized cables will be used for all the connections. An alternate cable configuration is also possible consisting of two double cables that are each separated into two “tails” closer to the offshore berth locations. Each tail could be a minimum of 500m in length

Where cables are buried onshore above the high water mark, suitable spacing between cables must be ensured to avoid de-rating of current flow as far as possible. The subsea cables need to be fitted with an appropriate termination that excludes water from the cables and enables them to be recovered to the surface for jointing connections to the WECs as necessary.

The electrical system will have switchgear located at the end of each cable in the onshore substation and protection systems against overload of the cable from a short circuit or fault on any of the WEC devices. A suitable earth system must be provided for the substation.

Generated energy will be metered by intelligent relays incorporated in the switchgear for each cable. Overall metering will also be provided for total export of electrical energy from the substation and a metered power import system will also be provided.

The substation building will be of robust construction and the finish will be in keeping with other buildings in the vicinity. There will be a security fence, gates and vehicle access routes and essential external lighting.

Ancillary equipment in the substation will include, but may not be limited to: uninterruptible power supply (UPS) for essential systems; communications equipment both for Marine Radio and to OWET/NNMREC’s remote offices as required; SCADA system (Supervisory Control and Data Acquisition) or DCS (Distributed Control System) to collect data on wave, and wind resource and store/transmit data as required; standby generator to power the substation in event of power loss and essential health and safety equipment. Security systems including CCTV and intruder alarms will also be provided.

Facilities for the testing teams and maintenance workers will also be included in the Visitor Centre. This will include desks, chairs and telephone, storage for tools, paperwork and personal items, welfare facilities (which may include: toilets, washing facilities and kitchen/messing facilities).

The detail of the extent of the facilities is a matter for detailed design and the planning of how the Test facility will be used by OWET/NNMREC and their customers who may submit devices for testing.

4. Test Devices

The Test Facility will incorporate up to four test devices for wave energy conversion systems.

Wave Energy Converters (WECs)

The types of device to be installed in the four wave berths are not known at the time of writing. If the devices are floating point absorbers, attenuators or similar, they should be moored in at least 50m depth in an area where the seabed is even and free from sudden depth changes or large obstacles. Fig 1 gives an ideal layout but in any case no two devices should be closer to each other than 200m at the extremities of their mooring footprint, which could be up to 500m diameter centred on the device itself.

Consideration should be given to the maintenance of the devices and the means of access to the device. EMEC advises that the devices should not be accessed at sea or any hatchways into them be opened unless the device can be properly restrained against a suitable vessel to permit the access in safety. The design of WECs should take this into account. The normal means of maintaining devices should be by taking them inshore to a sheltered harbour where they may be accessed in safety. This may be by towing or by lifting on to the deck of a vessel for transportation. The ability to remove devices from station and deploy moorings and umbilical to the seabed, such that they can be safely and easily retrieved, should be taken into account in the detailed design of the moorings and umbilical systems. OWET/NNMREC are strongly advised to designate the joint between the subsea cable and the umbilical to the device to be the limit of their responsibility.

Consideration should be given by the Technology Developers to the means of electrical connection of the devices by flexible umbilical cable to the permanent subsea cables of the Test Facility. This may be:

- Subsea plug-in connectors.
- Dry connection carried out on the deck of a work boat and sealed against water ingress.

The latter method is generally accepted as being the most effective; however it is still necessary to be able to unplug the umbilical from the device to allow for the removal of the device for maintenance. How this is done is a matter for the detailed design of the device.

Means of communication of data from the devices may be either by optical fibres contained within the cables or VHF radio from an aerial on a surface-piercing part of the device to an onshore receiver. The effectiveness of communications by VHF radio requires some testing prior to commitment to that design to ensure that loss of data is not unacceptably high.

EMEC advises, on grounds of safety, that every effort should be made in design to avoid the use of divers. Certainly, any system involving routine use of divers is best avoided. In the case of seabed-mounted devices that may not be readily removed to maintain, some diving may be necessary but care should be taken to minimise diving activity. Technology Developers should be encouraged to use innovative approaches so that the vast majority of operations, especially connection/disconnection, can be achieved by ROV or some other system.

5. Offshore Site Marking

In UK waters sites that are occupied by any permanent installations in the sea must be marked with buoys to warn mariners of the presence of obstructions, enabling them to avoid the area.

Sites are often marked by Cardinal Buoys – these are normally placed at the North, South, East and West extremities of the site. An example of a Cardinal Buoy is illustrated below.

Figure 2 South Cardinal Buoy

EMEC strongly advises OWET/NNMREC to determine the requirements in National and local legislation regarding marking the offshore obstacles which is what the test sites are considered to be.

It is not general practice to use these buoys for any other function such as data transfer which should be carried out using a separate buoy if required.

6. Cable Design - Offshore Cables

A number of factors drive the design of cables including:

- Route and length of cables
- Single or three phase generation[4] (devices which do not produce three phase should convert to this via a power electronics system onshore)
- Voltage drop which needs to be limited to around 3% or power losses in cables become too large (c. 5%)
- Selection of voltage for cable systems
- Permissible currents (Ampacity) of cables at the given operating temperatures
- Whether or not any future increased capacity is to be built into the cables
- Cost of cables with increasing conductor diameter
- Potential saving of cost by having cables of similar design for all the connections
- Cable Stability on Seabed
- Other cable content such as optical fibres and smaller sized power supply or trip signal wires
- Offshore cable ends with no device connected that enable testing of cables
- Power conditioning equipment.

This section reviews the approach to selection of cables, including preliminary consideration of the design drivers listed above. Whilst reference is made to economic considerations, EMEC is not familiar with costs in the USA and so suggested figures must be for the detailed design engineer to review carefully.

Some basic calculations of cable sizes and voltage drops have been made for the subsea cables in a spreadsheet associated with this report named "Cable Calculations (FINAL) Newport.xls" The general method of approach used is described below.

Cable Routes & Lengths

The cable lengths that EMEC used for the calculations are those indicated in the Feasibility Study[5] , as shown in the layout schematic in section 3, are various lengths for the possible wave sites. For purposes of this study 5% has been added to the Feasibility Study length to allow for uncertainties associated with detailed routing. These lengths have been used in the preliminary calculations and must be adjusted following determination of precise routes after surveys have taken place in detailed engineering. In ordering cables, an allowance should be made of at least 5% additional length for inaccuracies in survey estimates and possible diversions that may occur as the cables are laid. In addition, consideration should be given to retaining spare lengths of cable for possible repairs of any damage. In 50m depth of water, repair lengths of at least 300m should be considered and perhaps two or three such lengths stored securely on drums.

The total cable ordered should reflect both provisions mentioned above for each type of cable purchased and is a matter for the Detailed Design Engineer to determine.

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[4] See "All about circuits" http://www.allaboutcircuits.com/vol_2/chpt_10/2.html for single/three phase comparison
[5] "Feasibility Study for a Grid Connected Pacific Marine Energy Center", NMMREC/Oregon State University (2011)

Three Phase Generation at 60 cycles

EMEC has not been provided with design information on the types of generation that may be provided by the wave devices. Therefore, it has been assumed that three phase generation, which is the most effective in minimising power losses, will be employed. If this is not the case, the voltage drop calculations must be repeated for other types of generation that may be installed to determine whether there is any effect on the choice of cable size. The calculations in the associated spreadsheet[6] are based on three phase power generation. If the Detailed design engineer has any specific requirement for a different mode of generation, then this should be examined to determine the voltage drop that might result and the cable conductor size adjusted accordingly. The ultimate choice of generation and cable conductor size is a balance between various elements including the cost.

So assuming a three phase/3 conductor cable, a typical cable cross-section might be as in Fig 3 below:

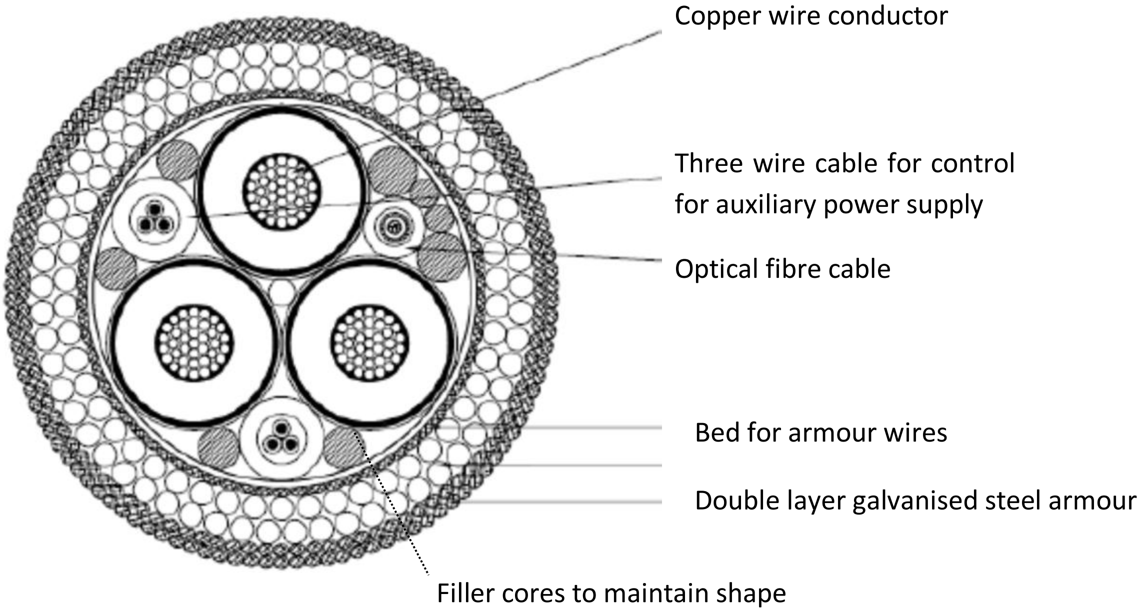

Figure 3 - Three phase/3 conductor cable

The cable shown has two three-wire cables incorporated for control signals or for the supply of power to the test device, these are optional as is the use of fibre-optic cable.

The next few subsections refer to the determination of conductor size from voltage drop and other considerations.

6 “Cable Calculations – Final xls “

Voltage Drop

The usual criterion for voltage drop in a transmission cable is 3-4% which represents an energy loss of around 8%. Clearly there is little advantage in having a system with a greater energy loss than 8%, so EMEC recommends the use of 3-4% voltage drop to determine the conductor sizes of the cable.
For the wave site cables lengths are considered for the Newport site as 11.13km

A cable conductor size of 150mm2 leaves allows operation at 6.6kV which could have several benefits:

- Currents will be a bit higher and may be easier to measure reasonably well at low production levels (see voltage choice below).
- Equipment for 6.6kV (especially connectors) are cheaper and more readily available

Further considerations are needed to determine the cable conductor sizes which are discussed later in this section.

Voltage Choice

These are the minimum sizes and voltages that must be used to remain within the 3-4% maximum voltage drop, however there may be advantages in use of larger diameter conductor cores as this builds in flexibility for increasing the capacity of generation connected at a later date. This is a matter for detailed design.

There are further issues to investigate to finally determine the best combinations of voltage and conductor size; these are discussed in the following two sections which address the need to include additional capacity for higher generation loads and the overall economics of the electrical system.

A further influence on the final voltage choice may be associated with very low currents which will be more difficult to measure with acceptable accuracy, particularly when the devices are operating in the lower portion of their load range. This may mean that a lower operating voltage and increased currents would be beneficial. Capability to operate at 6.6kV is an option that should be retained, except where excessive cost or some other important issue rules it out.

Need for Increased Generating Capacity

EMEC have been advised that a generating load of 1MW for each cable is the maximum required. It may be that some combinations of voltage and cable size will allow larger generating capacity to be connected if this should this be required in future. In this section the possible extra capacity is reviewed in brief.

The means of determining the extra capacity required is to estimate how much greater capacity could be handled if voltage drops along the cables were at the full 3-4% allowable. EMEC has no knowledge of OWET/NNMREC's possible future requirements, but recommends that some thought is given to the need for possible additional generating capacity in future. This will be a further matter for the Detailed Designer Engineer to address.

Permissible Currents (Ampacity) of cables

Ampacity is the maximum amount of electrical current a conductor can carry before sustaining immediate or progressive deterioration. It must not be exceeded so is a limitation to be considered by the Detailed Designer Engineer. The associated spreadsheet[7] shows that the limit may be encountered if the wave site cables are to run at 6.6kV.

The IEC standard 60092-352 (2005) lists the current carrying capacities with ambient air at 45^{o}C and the graph shown below it indicates how currents at other ambient temperatures may be estimated by application of the Rating Factors shown in the graph (see Fig 4 - below).

The "3-4 core" column should be read and the ampacity shown for a given conductor size multiplied by the factor corresponding to the ground temperature. This table is for 45^{o}C air temperature. The spreadsheet has a maximum air temperature of 30^{o}C which allows slightly higher ampacities.

Current carrying capacities in continuous service at maximum rated temperature of 90°C.
In accordance with IEC 60092-352 (2005) Annex B, Table B.4.

Conductor area mm²	1-core Amp	2-core Amp	3-4 core Amp
16	96	82	67
25	127	108	89
35	157	133	110
50	196	167	137
70	242	206	169
95	293	249	205
120	339	288	237
150	389	331	273
185	444	377	311
240	522	444	366
300	601	511	420
400	719	-	-
500	827	-	-
630	955	-	-

The tabled current ratings must be adjusted for ambient air temperatures other than 45°C.

Figure 4 Ampacities of various cable sizes

The problem of Ampacity does not generally affect the subsea sections of cable as the cable resistance is lower at the sea temperature (around 10^{o}C). However, onshore, in the section from high water mark to the substation, the cable will run at a higher temperature depending on the ground conditions and whether or not the cable is run in a duct or simply buried, and current limitations could come into force. The method for estimating this temperature de-rating limitation is described here. The Detailed Design Engineer should carry out calculations for the onshore sections to ensure any Ampacity limits are identified.
Appendix 3 contains a useful guide to derating the cable ampacity.

[7] See footnote 6

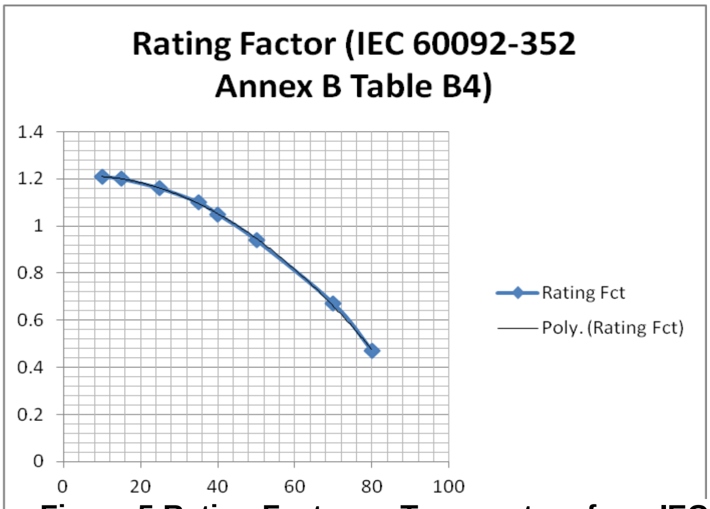

Figure 5 Rating Factor vs Temperature from IEC 60092-352

Cost of Cables with Larger Conductors

EMEC wishes to draw attention to some aspects of the costs involved in using cables with larger conductors. Although EMEC has no in-depth knowledge of the costs of electrical cables and other items such as transformers and switchgear in USA, EMEC would draw OWET/NNMREC's attention to the variation of copper cost for the conductors. This should be checked to revise the estimate at the time of detailed design as copper price fluctuates significantly.

Another option of "double cables" split into two "tails" close to the wave berths has also been examined.

Cable Stability on Seabed

In a tidal area the stability of the proposed cable on the seabed needs to be checked such that the cable will not be moved in the tidal flow. As the tidal influence in the wave test area is likely to be low, the problem of on-bottom stability will not arise. Cable stability may be addressed if necessary using Morison's equation viz:

$$V=\sqrt{(F \times w/d)}$$

Where V - the water velocity in km/hr at a right angle to the cable, W - the weight of the cable in kg/m and d - the cable outer diameter in m. F is a factor that should be assigned according to the type of seabed. So, for example, where bare rock bed is present, the value of F should be c. 0.2; where the seabed is more sand and/or gravel a figure closer to 0.5 may be appropriate. The velocity obtained should be compared to the likely peak velocity at the seabed level. This is unlikely to be an issue for the Newport site.

Other Cable Contents

Apart from the three insulated conductors, the cable to individual test devices may contain other cores that are required for data collection, power supply or transmission of trip or shutdown signals. These items are considered below:

Data Collection

It may be required to collect a range of data from the device under test concerning the electrical and/or mechanical performance of the device. Clearly, without a detailed knowledge of the test device, no information can be provided regarding the data to be transmitted. However, if significant data is likely to be collected the use of optical fibres will be necessary to provide the bandwidth to transmit the data. The advantage of fibre is that it requires no surface penetrating aerials or dishes to transmit data which would be necessary for V/UHF radio or Line-of-sight Microwave methods.

Optical fibres within the cable are usually housed inside a protective stainless steel conduit that can contain 4, 8, 12 or more individual fibres. It is usual to specify redundancy in case of damage to a fibre or loss of performance for any reason. Fibres may be joined at purpose-built panels to extend on for further transmission or interfaced with the data collection system.

V/UHF radio is a cheaper form of communication but has limitations in the marine environment due to interruptions of the line of site from waves to the aerial onshore and the bandwidth is much less than optical fibre. The consequence of this is that missing data levels are too high.

Line of sight (Los) Microwave has a better bandwidth than V/UHF but is dependent upon the presence of suitable infrastructure within good line of site to the test devices. A surface buoy is also required to carry the transmitter. Wave action can interrupt LoS Microwave but the installation can be designed to allow for diversity of movement to some degree. EMEC believes it is unlikely to be cost effective to install new LoS Microwave facilities unless it is possible to use existing onshore infrastructure.

Power Supply

The test devices may require small amounts of power to be provided to them if they are in a dormant state. This may be of the order of 1-2kW at, say, 400 volts, which can be transmitted via a three core wire with conductors in the 2-4mm2 size range. If this is a requirement the Detailed Design Engineer will need to estimate the acceptable voltage and voltage drop depending on the precise usage of the power. This can only be calculated for the specific circumstances, but the general formulae for calculation are similar to those used in determining the main conductor voltage drop.

A supply will be necessary from the local grid network with back-up from the emergency generator and the uninterruptible power supply (UPS) for the facilities, the latter items are described in later sections of this report.

Trip Signals

It may be required as a necessary safety feature of the design that there should be a signal generated if the grid fails or if a fault occurs on the test device that will shut the isolator at the device and the landward end of the power cable. A three or two wire connection within the cable may be included to carry this trip signal. This is a matter for detailed design and can only be finalised with a detailed knowledge of the test device(s) and the exact configuration of the substation circuits.

The rest of the cable content is made up of filler cores which are laid into the cable to preserve the circular shape of the composite power and communication cable as shown in the cable cross-section diagram earlier in this chapter.

Offshore Cable Ends

When a subsea cable is fully connected to a test device, there is not normally a problem with water ingress, providing the joint is well designed and the conductors are properly insulated from each other and the earth. One simple type of cable termination – the Henley Pulling Head[8] may be used to leave a cable on the seabed unconnected to a device. A diagram of a Henley Pulling Head is given in Appendix 2. It may be seen from the diagram that a space is left to cap the cable ends. This should be done with a suitably specified set of caps such as a "heatshrink"[9] variety. A typical example of this type of joint or end cap is also given in Appendix 2. It should be borne in mind that adequate testing of the cable – in a manner that is widely accepted by the power industry – will not be possible with this very basic end. A more sophisticated cable end should be considered if that is a requirement.

EMEC's experience with cable joints has been problematic in that some types of joint are affected by water ingress, either from the sea due to the pressure from the water depth or the joints are adversely affected by water that may be within the conductor cores. The cable conductors can function perfectly well if wet and if they are fully insulated, but if, when the cable is returned to the seabed after capping or jointing, any relative movement takes place within the joint or end, then leakage and shorting can occur.

Offshore cable conductors do contain a compound that is meant to "capture" water and limit its ingress along the cable. EMEC's experience shows that, despite the presence of the compound, water can seep along cable conductors to considerable distances. It is important to ensure from the start that water is kept out of the conductors or if they have been allowed to become wetted, then, a specialist joint that can maintain the integrity of insulation needs to be employed. EMEC advises strongly that the Detailed Design Engineer seeks specific expert advice on this aspect of design from an experienced cable jointing company. An example of the joint and method used[10] is by Thorne & Derrick UK.

The testing of the cables to ensure their integrity can easily be adversely affected due to shorting from seawater ingress. The testing is mentioned in the "Operation of the Facility" section of this report.

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[8] See http://www.wt-henley.com/products/Subsea%20Cable%20accessories.html and associated document "Henley Pulling Head Recommendation 635"
[9] See http://www.cablejoints.co.uk/sub-product-details/heat-shrink-cable-joints-cable-terminations/heat-shrink-cable-joints-XLPE-EPR-PVC
[10] See http://www.cablejoints.co.uk/upload/Marine-Cable-Joint-Kits---24kV-XLPE-Power-Cables-3-Core-Lead-Sheath.pdf

7. Dynamic Umbilical (connection from subsea cable to wave device)

Umbilicals are widely used in the offshore oil and gas industry. Umbilical is a general term for a combination of pipe, electrical conductors and optical fibres brought together into a composite cable-like structure. Umbilicals can be stiff and armoured and therefore static, like a subsea cable, or flexible and capable of operating in a dynamic (moving) situation such as the connection between a floating wave energy converter and a static subsea cable. Dynamic umbilicals are fitted with buoyancy to create a “W” or “S” profile enabling the flexing and movement of the umbilical to take place without excessive bending at tight radii that could damage the umbilical.

This is illustrated below in a diagram extracted from US Patent 6146052[11] which shows the parts of the subsea catenary profile of the umbilical: Section A is the externally stiffened length running up to where the umbilical plugs into the floating device (in this case the heaving buoy under test). The external stiffener prevents excessive bending or kinking of the umbilical to avoid damage as section A is the near vertical section of the umbilical. Section B is the submersible section that can have added weights if the self weight of the umbilical is insufficient and has a tendency to float. Section C has added buoyancy to create the “S” shape in the umbilical with an anchor point to the seabed that locates the umbilical close to the end of the static cable where it joins in a custom-designed joint. Note that the design of the umbilical in the patent is far more complex than that required for OWET/NNMREC’s purposes.

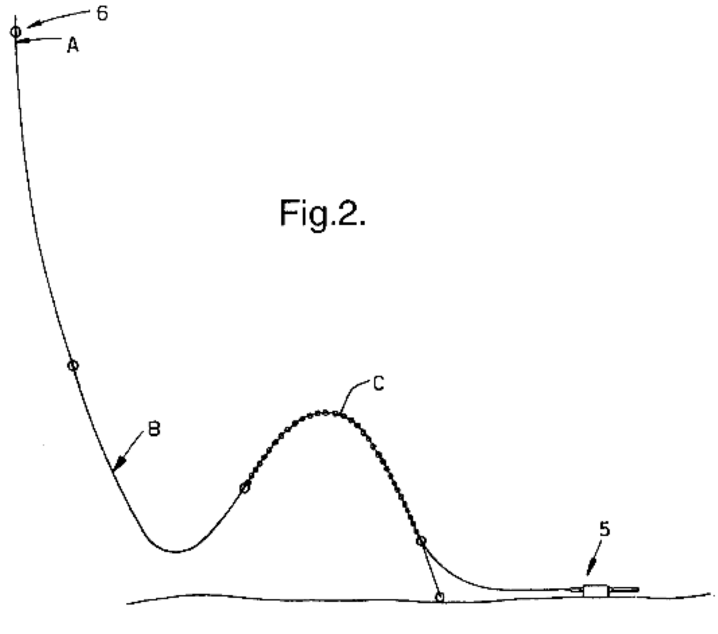

Figure 6 Diagram of the profile of a dynamic umbilical from US Patent 6146052

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[11] “Dynamic control cable for use between a floating structure and a connection point on the seabed”. US Patent 6146052, November 2000

The OWET/NNMREC umbilical might consist of: 3 copper conductors; one or two twisted pairs or triple wires to carry control signals and auxiliary power (if needed) to the wave energy converter and a steel tube to carry a number of optical fibres for communications. The umbilical may also contain a steel wire load bearing core to provide the necessary strength to the umbilical so that the other elements are not unduly strained.

A reputable company who have extensive experience in the manufacture of umbilicals is the Norwegian company Nexans Norway AS. A document describing their capabilities in subsea cables and umbilicals[12] can be found on their website. They are just one example of a company that can design and manufacture umbilicals, there are a number of such companies and OWET/NNMREC may wish to send a specification to a number of different companies. A guide to specifying umbilicals [13] is referenced.

[12] See: http://www.nexans.com/Corporate/2010/Nexans_Submarine-Technology_1.pdf
[13] See "API 17E_PGH_2009 Umbilical spec guide

8. Subsea Connectors for Cables

EMEC have made contact with Seacon[14] through their representative in the UK David Pye. He has recommended two of Seacon's products for consideration by OWET/NNMREC:
Hydralight – a connector for optical fibres

The picture shows the 8 channel wet mate optical connector by Seacon. A specification sheet is provided in the associated documents[15].

Figure 7 Hydralight Connector

CM 2000 – an electrical wet-mate connector by Seacon. A specification sheet is provided in the associated documents[16]

Figure 8 CM 2000 wetmate connector

David Pye, the Seacon representative, may be contacted at dpye@seaconbrantner.com ; telephone: +44 7830 772689 and address: 36 Swainsea Drive, Pickering, North Yorkshire, YO18 8PR, UK. EMEC advise that OWET/NNMREC contact Mr Pye to discuss the details of these products and their suitability for OWET/NNMREC's purposes at the appropriate time.

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[14] See http://seaconworldwide.com/about/
[15] See: "SAPL-DS-0001-HYDRALIGHT-Rev-19-low-res" available at the Seacon website
[16] See: "SAPL-DS-0014-CM2000-3.3kVAC-Rev-1-low-res" available at the Seacon website

9. Design of Onshore Cables

Onshore Cable Layout

The onshore cable design considerations must include the arrangement of cable routing from the low water mark, referred to as Mean Low Water Springs (MLWS), to the high water mark, Mean High Water Springs (MHWS) and on to the substation. As shown in the following schematic sketch, the cables from the subsea and land based test devices must come together in a suitable access pit that is waterproof and has a cover. This pit should connect to the ducts that lead into the substation building and to the lay-down area for power conditioning equipment that may be required for power coming from the devices.

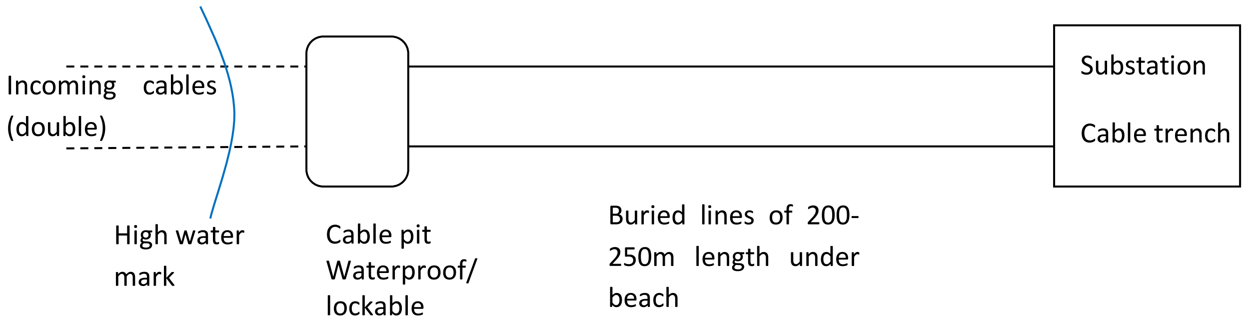

Figure 9 Schematic sketch on onshore cable layout

long distance the cables will need separation. Burial should be at least 1.25m below average sand surface for mechanical protection. With this layout Ampacity must be checked for thermal de-rating requirements, this has been carried out in a preliminary way and is summarised in the table below.

Many of the principles that apply to offshore cables also apply to onshore, for example the voltage drop calculations and conductor sizing.

Current Rating of Onshore Cables

One key difference is that the onshore cables are either buried in the ground or routed within protective conduits or cable trenches. Unlike subsea cables they are not surrounded by a natural cooling medium so there may be need to consider thermal limitations arising from both the way the cables are laid and the distances between them which may reduce the cable Ampacity.

IEC 60287-2-1 Electric Cables – Calculation of Current rating – part 2-1 Calculation of thermal resistance, is the Standard that may be used to calculate the limitation of current that may arise from the cable configuration in the ground or duct. Appendix 3 Guide to Thermal De-rating of Cable Currents' provides a summary of the methodology of calculations following the standard for a buried three conductor cable coming ashore to a substation. This is to show the method only and the numbers are not directly applicable to OWET/NNMREC's facilities. The Detailed Design Engineer will need to run such calculations for the chosen design layout of cables.

10. Power Conditioning for Test device Power Production

Due to the nature of some test devices they may not produce ac power at 50 cycles and the appropriate voltage. In such cases, power conditioning equipment mounted in a container or on a skid in a shelter will be necessary to produce power that can be transformed down to the users' 220v ac.

EMEC cannot advise further on any detail relating to this equipment as there are no specified test devices. The Detailed Design Engineer of the test device will be the best suited to design power conditioning equipment and they should be provided with a specification of the conditions required on the inlet transformer to the public supply. They will also need details of any relevant grid code or legal definition of power quality to meet user requirements. The UK has a number of codes that specify power quality such that it is free from stray harmonic frequencies that may cause "flicker" on television sets, interfere with telephone systems or prevent some domestic appliances from functioning correctly. It is a matter for the Detailed Design Engineer to investigate these aspects to ensure that power supplied from the test devices is appropriate for the user community.

An example of a power quality meter is that from GE Mutilin[17].

[17] http://www.gedigitalenergy.com/multilin/catalog/pqm.htm

11. Substation Scheme - Electrical (Switchgear, protection etc)

The sketch plan of the proposed substation layout is shown in Appendix 4 and is for general guidance of the Detailed Design Engineer.
The example Single Line Diagram (SLD) for a typical substation is given in Appendix 6. This is for illustrative purposes only and is not a proposed design for the OWET/NNMREC facility. However, a similar diagram detailed for the required Facility is a necessary deliverable for the Detailed Design Engineer to produce. The drawing also notes a number of other key deliverables to define the electrical system including but not limited to:

- Equipment List
- Equipment Power and Earth layout
- Cable Routing layout for the onshore site and route from the beach landing of the offshore cables
- Cable Schedule
- Earthing Single Line Diagram
- Distribution Board Schedule
- Interconnection Diagrams.

It is a matter for the Detailed Design Engineer to determine the full list of deliverables required to define the system adequately.

The system should include a power take-off for supply to all ancillary equipment, as well as the lighting and small power circuits for the building. For a 6.6 or 11kV system, IEC62271-200 is the applicable standard for switchgear up to 52kV. Other parts of the IEC2271 standard are applicable to other aspects of medium voltage design.

Earth protection design is a key feature of the electrical system – a recognised standard should be followed by the Detailed Design Engineer. Two examples of standards are: BS 7430:1998 and ENA TS41-24[18], both of which are commonly used in the UK.

The Detailed Design Engineer should verify that the most recent versions of standards are used as the basis of design.

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[18] BS 7430: 1998 Earthing Contents and ENA Technical Specification 41-24 Issue 1 1992

12. Building layout

Building layout is an important feature of the substation design and the detailed design engineer must consider a number of important features of the design, including but not limited to:

- Positioning of cable ducts for all cables, both for incoming and outgoing power, these ducts must allow for appropriate bending radii of cables and be large enough to provide suitable separation of conductors to avoid thermal overload. They should also reflect the entry position into switchgear and other equipment. EMEC has preferred bottom entry as the most convenient configuration.
- The positioning of the main banks of switchgear and control cabinets to ensure that adequate clearance is available for maintenance access and for routine testing. This must follow from the selected switchgear.
- Control of access to the main switchgear to protect any person who is authorised to be in the building (e.g. to access control and communications cabinets) who may not be authorised to operate switchgear. Any local regulations regarding authorisation to operate must also be borne in mind.
- Facilities required for personnel who will be working in/around the building from time to time. This may include office workstations, kitchen facilities and welfare facilities (toilets, first aid box etc) and storage space for any essential equipment and documents.
- Location of lighting (normal and emergency provision) and small power sockets for instrumentation and appliances, including heaters.
- Provision for a standby generator to provide power in event of grid failure.
- Data ducting and connection sockets.
- Positioning of any other ancillary equipment required for the facility, including communications such as marine radio.

Error! Reference source not found.contains a conceptual layout of a substation and an administrative building. Whilst this particular layout should be adapted to OWET/NNMREC's needs, the detailed design engineer will find it a useful starting point.

Other aspects of the site design that the Detailed Design Engineer must bear in mind are:

- Requirements of local planning regulations, this may include height and external appearance.
- Requirements for lay-down areas for any equipment necessary to condition power from the test devices to a suitable ac output.
- Vehicular access and parking spaces including a turning circle for lorries or articulated vehicles delivering equipment.
- Security arrangements such as fencing, gates, CCTV, external lighting and intruder alarms
- Connections to utilities including water & drainage

- Any other specific requirements that may be requested by OWET/NNMREC.

The choice and incorporation of these features is for the Detailed Design Engineer to consider in response to OWET/NNMREC's directions. EMEC believes that the above guidelines will be sufficient to allow the Detailed Design Engineer to specify the substation site.

13. Grid Connection

EMEC have not been provided with details of the local grid. The design of the grid connection is very much a matter for the Detailed Design Engineer in conjunction with the local network operator.

One of the EMEC draft standards and guides produced in 2009 is "Guidelines for Grid Connection of Marine Energy Conversion Systems" which will be provided as an associated document with this report; the contents page of this document is shown in Appendix 6 Grid Connection Standard – Contents.

14. Grid stability

EMEC has assumed that there is no issue with Grid stability at any of OWET/NNMREC's proposed sites. If this is not the case the Detailed Design Engineer will need to take appropriate action.

15. Measurement Devices

There are a number of options for the measurement of wave resource. The main types of instruments are:

- Wave riding buoys - a heaving buoy which is slack moored to a clump weight and connected with a rubber "Bungee" to allow free movement. The buoy contains accelerometers that respond to movement in N-S, E-W and vertical directions or a GPS system. On board equipment stores data and transmits it via VHF to a base station where dedicated software "Waves@21" computes the spectral energy in the waves. A buoy of this type is offered by Datawell bv[19]. See Appendix 7 Wave Measurement Instrument.
- Acoustic Doppler Profiler (ADP) (example, AWAC) [20] - this instrument, placed in a frame on the seabed, uses high frequency sound waves to track the profile of the surface and collects data on both wave height and direction in on-board memory. Data is pre-processed to extend memory life. A data sheet is provided as an associated document with this report.
- X-band radar – this uses the backscatter from ocean waves to analyse the wave heights and direction over the area of interest. There are two main software systems: Seadarq[21] offered by Nortek AS and Wamos (R)II[22] offered by Oceanwaves. The range of X-band radar is a few km from the base radar tower and the output should be validated by a wave rider buoy or ADP.
- HF- Radar – this technology can measure ocean currents and wave height and direction at distances up to 200km offshore. The system needs at least two base stations and costs much more than X-band radar. Helzel Messtechnik Gmbh market the "WERA" system,[23] a commercial HF radar product.
- Secondary, Non-directional methods available include:
  - Wave "staff" is a water height measuring device[24]
  - Wave Radar from RS Aqua Ltd[25]
  - Pressure gauge RBR,Valeport[26]

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[19] See http://www.datawell.nl/inhoud.php?id=3
[20] See http://www.nortek.no/en/products/wave-systems/awac
[21] See http://www.seadarq.com/seadarq/about-seadarq
[22] See http://www.oceanwaves.org/start.html
[23] See http://www.helzel.com
[24] See http://www.rsaqua.co.uk/waveradar.php
[25] See http://www.rsaqua.co.uk/waveradar.php

EMEC has been using the Datawell wave buoys for 10 years, the instruments can be calibrated to meet the requirements of ISO 17025:2005 which is the international standard for a measurement laboratory against which EMEC is accredited.

Detail of wave resource measurement may be found in the EMEC Wave resource measurement standard[27] and the draft IEC Wave performance Measurement Standard.

26 See http://www.rsaqua.co.uk/waveradar.php
27 Assessment of Wave Energy Resource, EMEC, 2009, ISBN 978-0-580-65657-6

16. Weather Station

A suitably positioned weather station should be provided, measuring wind speed and direction, air temperature, relative humidity, barometric pressure and dew point. The instrument should be positioned in an open area without obstruction to the wind or sharp changes in ground level within 200m if possible. The anemometer should be between 4 and 10m above the ground. A typical device is the “MetPak II” by Gill Instruments[28] which is illustrated below:

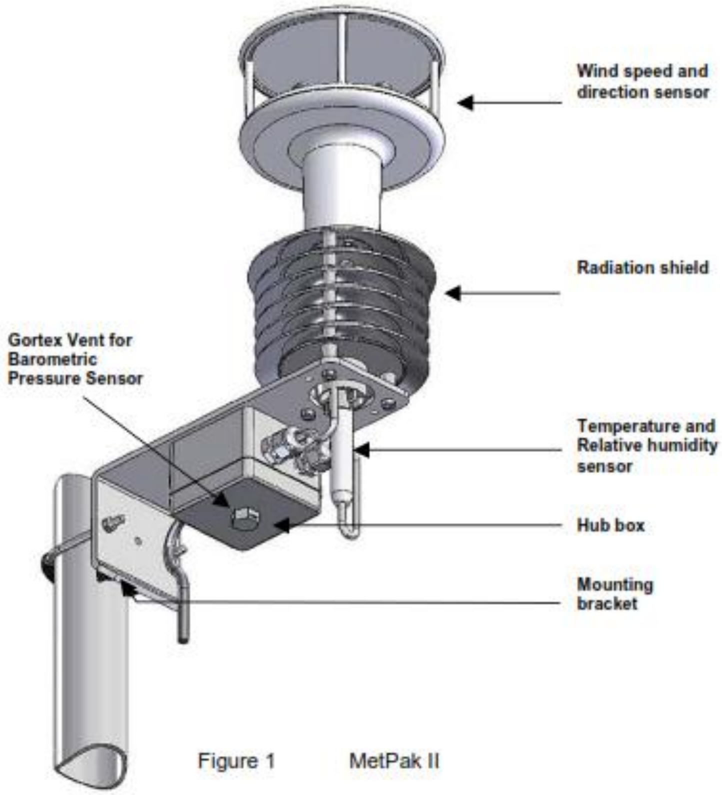


Figure 10 MetPak II weather station

A datasheet for this device is provided in an associated document with this report “MetPak II Weather Station”. The system can be mounted on a pole with a networked connection to the communications system. Software for the system monitoring, recording and data analysis is available from the vendor.

[28] See http://www.gill.co.uk/products/anemometer/metpak_main.htm#weatherstation

17. Metering of electrical power

The OWET/NNMREC Test Facility will require metering on the individual incoming power on circuits from each test device as well as an overall meter on the outlet power from the substation. Metering must be capable of measuring power imported to as well as power exported from each test device, so that accurate net power production can be measured for all devices. The design engineer should bear in mind that not only the aggregated power produced by a test device will need to be measured, but at certain times in the testing process the rate of power produced by the device must be constantly monitored and recorded.

Consider the situation where, for example four devices are producing power and two are not, but are instead importing power. Then the imported power will come from the bus-bars in the substation and will reduce the output from the substation. It is important to ensure that the metering arrangement allows the true power outputs of each device to be determined to match the measurement of resource.

Although standards for performance measurement of wave and tidal devices usually state that power output should be measured at the generator terminals of the device, this is often impracticable, therefore losses in cables, power conditioning equipment and transformers must be evaluated to infer the true output of the devices from the onshore measurement. Electrical measurement is as per the EMEC Measurement Standard (see references), also see the Appendix 13 outlining the losses in cables.

Metering at Substation Outlet

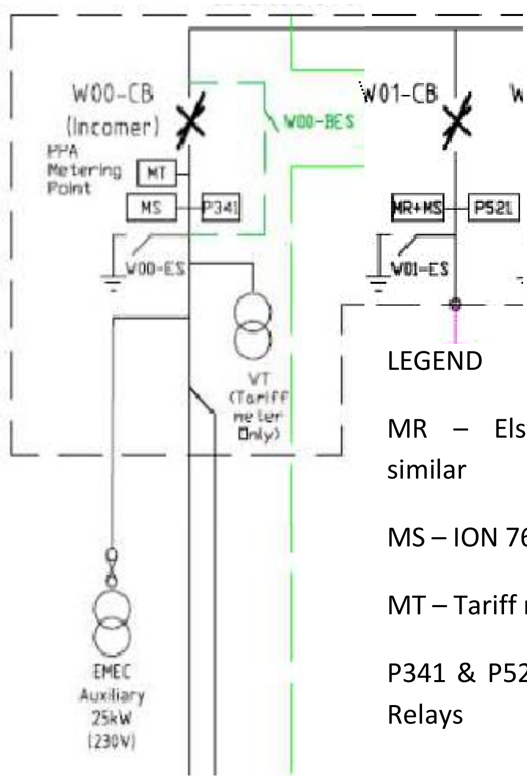


Figure 11 Elster 1700 Meter

LEGEND

MR – Elster A1700 or similar

MS – ION 7650 or similar

MT – Tariff meter

P341 & P521 - Protection Relays

EMEC use the Elster 1700[29] as the meter for each Berth and the ION 7650 transducer to interface with the SCADA system. Figure 13 shows an incoming cable from one device with the meter and protection relay arrangements for the outgoing supply to the grid with a tariff meter installed which is the meter for the power purchase agreement (PPA). The auxiliary supply to the substation is also shown at the left of the diagram. This diagram is indicative only for the guidance of the detailed design engineer and is not a design in itself.

The SCADA (Supervisory Control and Data Acquisition) system is described in the next Section.

Appendix 9 gives a list of the data to be supplied and recorded from the metering.

[29] See Appendix 9

18. SCADA System

The SCADA system is a vital part of the Test Facility equipment. It is a computer based system that receives, selects and stores data for reporting and analysis. All outputs of permanently installed measurement devices need to be interfaced with this system to enable test results to be calculated and reported properly.

Appendix 10 shows an example of the overall system architecture for both EMEC sites. The principle of operation of SCADA is shown in Figure 12.

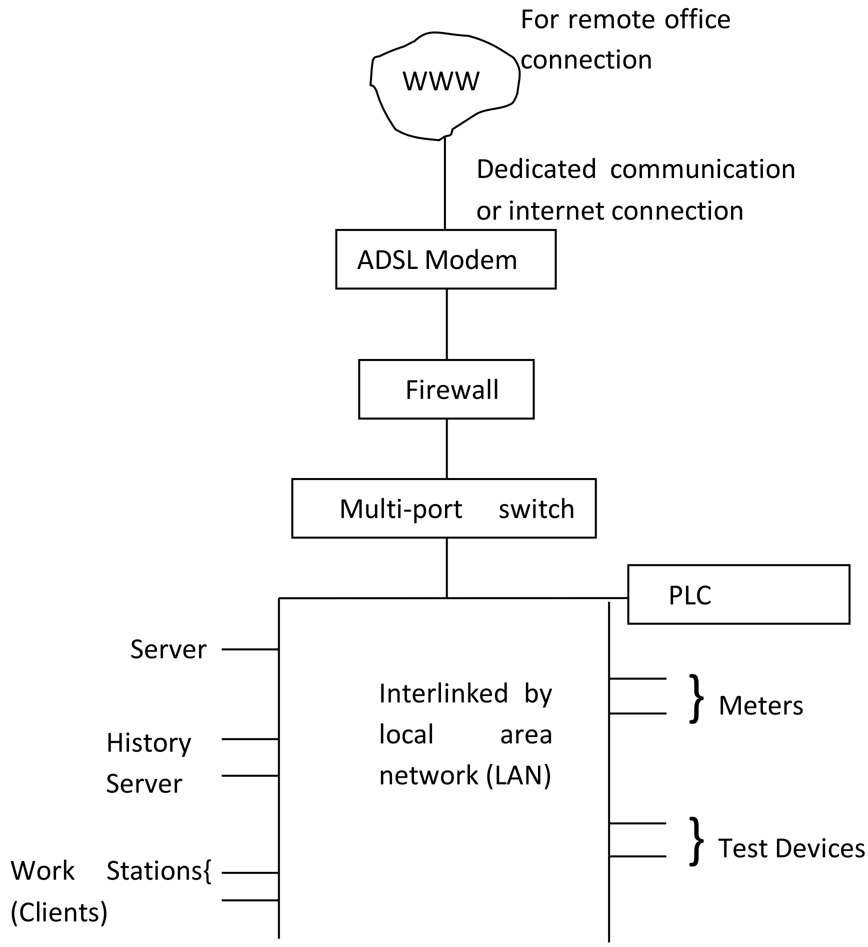


Figure 12 Principle of Operation of SCADA

The data sources (meters, device instruments etc) and the servers, workstations and controller are linked by a standard network as a LAN or extended area network and then via the internet or some other dedicated communication link (this may be optical fibre, LoS Microwave or similar depending on required bandwidth) to remote office or control locations. The system must be defined to provide defined functions at locations which could include: receipt of data in raw or processed state, storage and retrieval of data, display of data and remote operation with access protection.

The process for definition of SCADA begins with a statement of operational functions listed by location together with an associated operational philosophy (an example of the latter is the statement found in the later section titled “Operation of Facility”. This is followed up by preparation of a Functional Design Specification (FDS)[30] which contains enough description to enable the System Designer to identify suitable building blocks of hardware, firmware and software, with the appropriate communication protocols, to fully specify the system for purchase and assembly.

SCADA requires a careful testing programme that takes place in the factory (Factory Acceptance Test - FAT) and then, when assembled on the site(s), the Site Acceptance Test (SAT). Such testing includes functions of the hardware, integrity of communications and end-to-end tests that demonstrate that input data is replicated at the workstations and in the server databases.

The capacity of the data handling system is an issue that may affect the available modes of communication. Ideally the internet can be used, but only if it has sufficient speed to accommodate the data flows required. If this is not the case, other methods must be utilised, although these may be more costly than the internet.

The man-machine interface (MMI) is an important aspect of SCADA to specify display requirements in terms of function, colours, location and type of alarm displays, remote operation facilities and voice and data communications.

EMEC recommends careful thought concerning the functions and accessibility to the SCADA system and avoiding “cutting corners” in defining the requirements of the system. At times economic considerations may call for compromise instead of building in every ideal requirement. Most providers of these systems will be able to offer work-around solutions to prevent excessive downgrade of requirements.

EMEC emphasises that the material in this section on SCADA is not a design as such but offers a framework and guideline for the Detailed Engineering Designer.

[30] An example contents page of an FDS is also given in Appendix 10

19. Communications Requirements

There are a number of communications systems that may be relevant to the operation of the OWET/NNMREC Test Facility, these include:

- *Routine telephony* – this may be landline or mobile based and dependent on any existing systems at the location.
- *Marine Radio* - Ship-to-shore/Shore-to-ship marine band radio for co-ordination of offshore activity, including the agreed emergency channel for communications and vice versa in event of emergency.
- *Data Communications* – this may be by internet, optical fibre or line-of-site microwave communications to achieve the bandwidth required.
- *SMS Messaging* – To avoid full time manning of control points, the SCADA system can be designed to provide an SMS message to a duty officer's cell-phone or to ring a landline to advise that an alarm situation exists.
- *VHF Radio* – This may be required for data transmission (e.g. from a wave-rider buoy) or may be used as a further form of communication as a back-up to normal systems.
- *Local Hand-held Radios* – These may be required for local communications during testing and maintenance activities either on or offshore.

It is a matter of Operational Philosophy and the decision of the Detailed Design Engineer to determine which of the above means of communication are to be incorporated into the Facilities.

EMEC would remind OWET/NNMREC's Design Engineer that radio communications may be governed by local or State Government legislation and the requirements of this must be observed to obtain appropriate licenses and permits and to meet any specific technical standards that may be associated with the legislation.

20. Uninterruptible Power Supply (UPS)

This supply is maintained by batteries to provide 30 -60 minutes of back-up power to essential instruments in the event of a delayed start to the emergency generator. A suitable vendor of these systems is Eaton PW9130[31] series with battery packs to give cover for 30-45 minutes downtime. A sample specification of this type of system (Eaton 9130 UPS) is provided with the report.

Figure 13 Example of UPS device

The Detailed Design Engineer should ensure that the necessary systems for SCADA, communications and the services to the building, such as the Fire/Security system, have all been specified so that the power consumptions can be added up and a contingency amount (20-50%) included for future expansion of equipment. The extent of the contingency is a matter for the detailed design engineer to determine.

[31] See http://powerquality.eaton.com/UPS/selector/SolutionEMEA.asp?SOLID=650539&ResellerIDCode=1

21. Standby Generator

The standby generator is there to support the facilities for up to 24 hours in event of a failure of the grid. It will maintain lighting, power to instrumentation so that monitoring and control is not lost preventing unsafe situations arising. The generator will need to generate approx. 25kVA at 110volts (single phase) and is of the type shown in the associated document "FG Wilson P26-1S"[32].

Figure 14 A typical image of the generator type

In general, the generator should be able to support the following approximate power requirements:
Substation lighting (1.5kW)
Substation small power (3kW)
Substation instrument supply (via transformer) (3kW)
Switchgear closing/tripping supply (3kW)
Fire and security system (1kW)
Substation heating/cooling (8kW)
External lighting (0.5kW)
Data equipment (SCADA) (3kW)
Generator own use (0.5kW)

The power usages given above are indicative only and should be derived by the Detailed Design Engineer once the equipment has been selected to ensure the capacity of the generator is adequate. The designer should also note that a three phase power supply may be preferred for improved stability of the electrical system.

The generator should be housed in a separate enclosure from the other parts of the substation building with direct access to external air supply. The generator should be fire-protected by a fusible link[33].

[32] See http://www.fgwilson.com/cda/files/2076241/7/P26-1S%284PP%29GB%280211%29.pdf
[33] A fusible link is a taut wire device with a link that melts and severs rapidly, thereby closing the generator down and shutting off the fuel line, in the presence of fire.

The diesel fuel tank should be sized to contain 24 hours supply at 100% output of the generator plus a margin of at least 25%. In the case of the machine indicated, an hourly usage of 2 gph (US) is required, so a suitable tank should hold at least 60 US gallons of diesel. The tank should be sited outside the substation building in a bunded area that can contain the full contents of the tank in event of a serious leak. The supply pipe to the generator should be in steel suitable to withstand damage by fire.

22. Closed Circuit TV

As the substation site at the test facilities will be normally unmanned, there is a need to maintain security with fencing and the use of CCTV to show areas outside and inside the building. It is important to include the HV switchgear area as only authorised personnel should enter it and any visitor or non-authorised person should be accompanied.

Externally, the immediate vicinity of the building would need to be covered and OWETNNMREC may wish to consider having controllable cameras that can view the wave and tidal berth areas. The value of this is, that if there is any unauthorised accessing of the sea around the devices, records of the camera views can be held on the SCADA history server for, say, 24 hours giving time for the record to be accessed after any incident.

A data sheet for the type of camera[34] that EMEC have used can be found in

[34] Axis M10

Appendix 11 Axis Network Camera Series Datasheet.

23. Health and Safety Equipment

Appropriate equipment for welfare health and safety should be provided at the substation. This should include, at least: fire extinguishers (CO_2 type); High Voltage rescue equipment (including insulated personnel hook and gloves); First Aid kit; Eyewash kit; Torch with mains-charger facility also personal protective clothing for visitors.

Signage should be erected to comply with local and State legislation and to clearly designate areas where access to live electrical equipment is situated and to forbid interference by unauthorised persons with any equipment, other than designated MMI's and computers. First aid instructions including dealing with electrocution and the administration of heart massage, with clear graphics, should be posted in the substation.

Any other local factors that may impact health and safety should be evaluated by the Detailed Design Engineer and appropriate measures included in the design and equipment provided to minimise any risk.

24. Health and Safety – General

Electrical Equipment operating at any voltage above that of the normal 110v power supply should be operated and maintained only by suitably qualified and authorised personnel. The prevailing regulations for electrical safety and working with electrical equipment must be properly followed in design as well as in operating instructions and guides.

Consideration should be given in the design process for such matters as the need for lone working at the substation site. Risk assessments should be carried out and recorded and appropriate facilities provided as well as a specific operating instruction for lone working.

Personnel working with the substation equipment should be properly trained and qualified to do the tasks they are called upon to perform.

Safe systems for electrical work must be implemented fulfilling both national/local regulations and that are in line with international standards. These should include supervision by an Authorised Person who is qualified in handling and operating high voltage systems and the control of the work of subcontractors and access of visitors to the site. This should include systems for locking off electrical circuits to be worked on and permits to work for non-electrical works as well as other Electrical safety rules that are advised by the Detailed Design Engineer.

Some other aspects of health & safety (H&S) are covered in the following section on Operating Philosophy.

25. Operation of the Facility

This section consists of a high-level operating philosophy for the test site inclusive of the offshore test berths, cables and electrical equipment, buildings and services.

GENERAL

The Test Facility will provide four offshore test positions as described in Appendix 1.

Each of these test positions will be connected to the substation and have appropriate communications links back to the substation and the offices or control point of the Users. It is envisaged that the Users of the Facility will provide their own cable system for connection onto the Test Facility cables. The connection arrangement will be provided by the User as agreed with the Facility Operator (Operator) and the end of the Facility cables will be the division point between Operator and User. Activities around each berth location will be coordinated by the Operator.

The communications link from the shore base to the device under test will be via an optical fibre, which will be laid up as part of the cable. Alternates of VHF or line-of-sight microwave may be investigated as necessary.

ONSHORE

Onshore Substation

The test positions will each be fed from a circuit breaker which will be connected to a common busbar at 6.6kV. Each circuit breaker will be fitted with its own metering and protection system giving each test device a generating load up to 1MW at 0.95 power factor. It is envisaged that the test units will have power conditioning either on board or at the substation lay-down area. Pilot wire tripping may be required from the offshore device to the onshore switchgear, as some devices may not have circuit breakers on board. The protection system and the circuits feeding the test devices will consist of a digital over-current / earth fault relays. Also fitted to each circuit breaker will be a multifunction metering unit able to meter imported and exported power and fitted with a communications port to link to SCADA.

The incoming circuit breaker would also be fitted with a digital protection relay and such other conditioning that may be needed for embedded generation, these would be arranged to trip the test device circuit breakers. The overall substation metering would be undertaken from the incoming circuit breaker. The operation and ownership of the incoming circuit breaker may be with the substation or the local network operator.

The substation building may also house a standby generator (if required) to maintain power to the Facility in event of grid failure. The generator will be sized to power the services within the substation building. A UPS will support the communications and essential instrumentation system during a changeover for up to 30 minutes.

Background Monitoring

The sea conditions will be continuously monitored using a wave rider buoy situated near the test device berths. Each will relay by VHF radio to the Data Centre wave height, period and direction. Current strength and direction may also be monitored. The weather station located onshore will measure wind speed, direction, barometric pressure, temperature & humidity.

Support to Operations

The safety operation of the Facility is a critical for all personnel involved in the use of the Facility. It is therefore of paramount importance that the Operator is able to ensure the safe connection onto test devices and safe operation of the facilities provided. Further, the Operator should ensure that any structures to be placed in the sea are fit for purpose.

The Operator will initially need to be satisfied that any new device proposed for test is safe to connect onto the cabling. This will probably be by means of a submission of a third party design review of the electrical systems. For the offshore devices, an independent review of the structure of the test device will also be needed to minimize the chance of failure of a device structure that the User is unable to rectify. Such reviews may also be required to ensure compliance with the local or National Regulations.

EMEC recommends that a permit system is established for Users to access the cable end and enter the sea area around the Facility with construction vessels or workboats. Prior to the start of installation on site, a review of the essential safety requirements and method for the work should be carried out with the user. This would normally include a Hazard

Identification and Risk Assessment (HIRA), from review of the methods and procedures, the Facility Operator can gain assurance that a safe system of work is to be implemented.

When the electrical connection is to be made, the Facility will test the cable to demonstrate its fitness and then will issue a certificate showing that the electrical supply to that cable is isolated. A permit to work can then be given to the User who will carry out the connection and retest the cable, the isolation certificate may then be signed off once the final connections were made and the Operator and the User are satisfied of the safety of the connection and system on board the test device before it is re-energised.

All operation of the equipment within the substation would be the responsibility of the Operator, Developers will not be allowed to operate the HV switchgear. Rights of access to the switchgear room will be limited to the Operator. Inspection of the facilities by the User may be carried out with the Operator's Authorised Person present throughout.

It is envisaged that the communications system between the devices and the data centre will be a straight- through optical fibres with VHF radio as back-up. Therefore the input from the Operator for this section of the communications centre will be limited to ensuring that the system is correctly routed through from the test device cables to the SCADA.

The operation of the permanent data collection devices, such as the wave rider buoy, Meteorological station and metering will be the responsibility of the Operator. These data will be available to the Users at the Facility and relayed to the User's via the internet and will also be archived for an indefinite period.

Personnel Requirements

The Operator will supply personnel with training and authorisation to allow the safe operation of the switchgear. This will include the capability to issue Isolation Certificates and Permits to Work.

Independent safety validation will be undertaken by a suitably qualified external authority such as a certification authority or appropriate consultant.

The operation of the data network will be by the Operator who will contract for maintenance of the systems by an appropriate IT specialist or employ an in-house specialist.

Maintenance of the Waverider Buoys, Met Station and Video System will be let to the equipment suppliers or suitably qualified local companies.

The Operator will be responsible for continuous monitoring of the facility including offshore and onshore equipment. The SCADA system can assist with this if it is necessary to avoid manning a control centre 24/7. The SCADA can be engineered to send SMS messages in event of alarms being received. A system of duty officers, who carry the cell phone on a rota basis, can assess any alarm calls and take action in accordance with the operating procedures. The detailed design engineer will need to assist the Operator's personnel to develop the procedures, which should cover routine and emergency situations. This is an area that EMEC may also be able to assist with in future. Appendix 10 contains a sample alarm list for a similar (but not identical) facility that can be used to assist the Detailed Design Engineer and Operator to draw up the required operating instructions and design the matching system within the SCADA.

Maintenance Facilities

The Operator may provide small workshop facilities the repair / modification of electronic and small equipment by the Users. This may form part of the facilities available to the Users.
OFFSHORE

The safety of the offshore facilities will be monitored by the Operator from the aspect of integrity of navigation aids and station keeping of devices. Users will be required to include appropriate systems in their devices to allow monitoring of station keeping of moored devices. The following items are identified as the interfaces that should be maintained between Users and the Operator for the range of offshore activity that takes place.

Installation

This will be the Developer's responsibility, however the Centre Operator retains the right to review the proposed procedure to ensure the Centre is safeguarded. The installation warranty surveyor's report and advice should be lodged with the Centre and communication arrangements set up for the installation activity itself.

Mooring

The type of mooring varies between devices. The Operator does not provide the mooring and electrical riser. The means of attachment and any special requirement such as a "break free" weak link for floating devices (to avoid damage to the subsea cables) must be agreed between the Developer and the Centre. Moorings should be supplied and installed by competent suppliers and contractors who co-operate with the Centre in notifying entry and exit from the designated Centre area(s) and advising promptly of any potentially dangerous or damaging events. Moorings should be certified or verified appropriately and the Operator supplied with relevant reports on these aspects.

Marine Facilities and Maintenance

These are the User's responsibility and they should make maximum use of local companies, providing they can offer the skills and capability required. A system of notification for routine and unscheduled maintenance activity will be agreed between the Operator and each User.
The onus is on Users and their sub-contractors to maintain high standards of health safety and environmental management at all times. Users should permit the Operator to review and

hold copies of their Health Safety & Environmental procedures and Emergency Procedures so that the Operator can play any necessary role in the event of an incident or accident. Similarly the Operator should ensure that all necessary documentation, including Emergency Procedures, is provided to Users.

26. Suggestions for Further Work

EMEC has a number of recommendations for further work in follow up to this report. The suggested work items are:

Review of selected key documents produced in the conceptual and detailed engineering activity for the facility. This might include, but not be limited to: Cable routing and cable lengths Report; Cable Technical Specification; Single Line Diagram for the Substation; Substation Building and Lay-down Area Layouts; Instrumentation Specifications and the Environmental Statement or Environmental Impact Assessment (EIA).

Specific review of Functional Description document for SCADA system to ensure the functionality meets OWET/NNMREC requirements in addition to good practice.

Writing a Management System for Health & Safety, Environmental and Quality Management. This would include the high level manual describing the policies and arrangements to implement them, also the procedures for operating the facility, and the standard record forms that are required for device testing, routine operations; offshore operations; maintenance system and health, safety and environmental management.

Preparation of a Permit-to-Work system and a Permit-to-Access Offshore Sites system, including overall rules, format of permits and checklists of matters that must be attended to in order to issue permits.

Review of Resource Assessment and Survey progress including relevant reports and method statements.

Review of overall plans for the test facility including schedules.

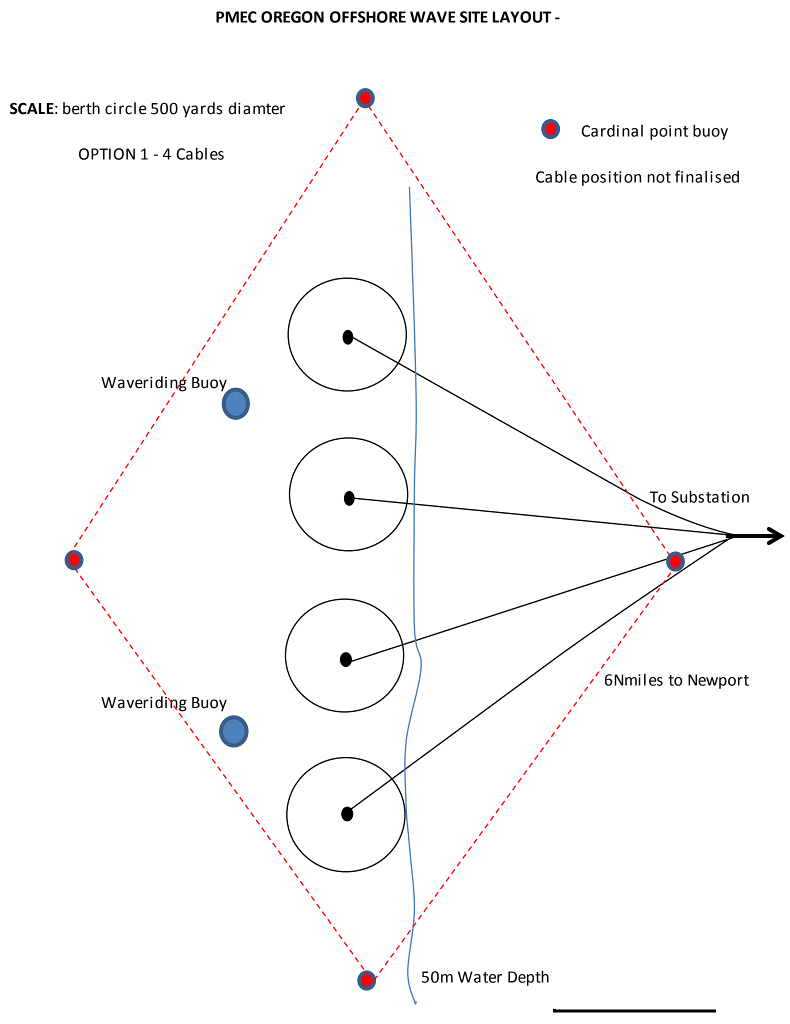
Provision of support personnel for critical parts of site testing of facilities, early deployment and testing of wave and tidal devices.

Appendices

Appendix 1 - Conceptual Cable Layout (not to scale)

The sketch below shows a conceptual scheme for the Test Facility layout which consists of four wave berths. The notional cable lengths are shown for two possible sites and the exact lengths will be subject to detailed design. The distances comply with those indicated by OWET/NNMREC.

It is proposed to use a common cable type for all test berth connections. A typical cable specification is supplied (for guidance of the Detailed Design Engineer) as an appendix of this report.

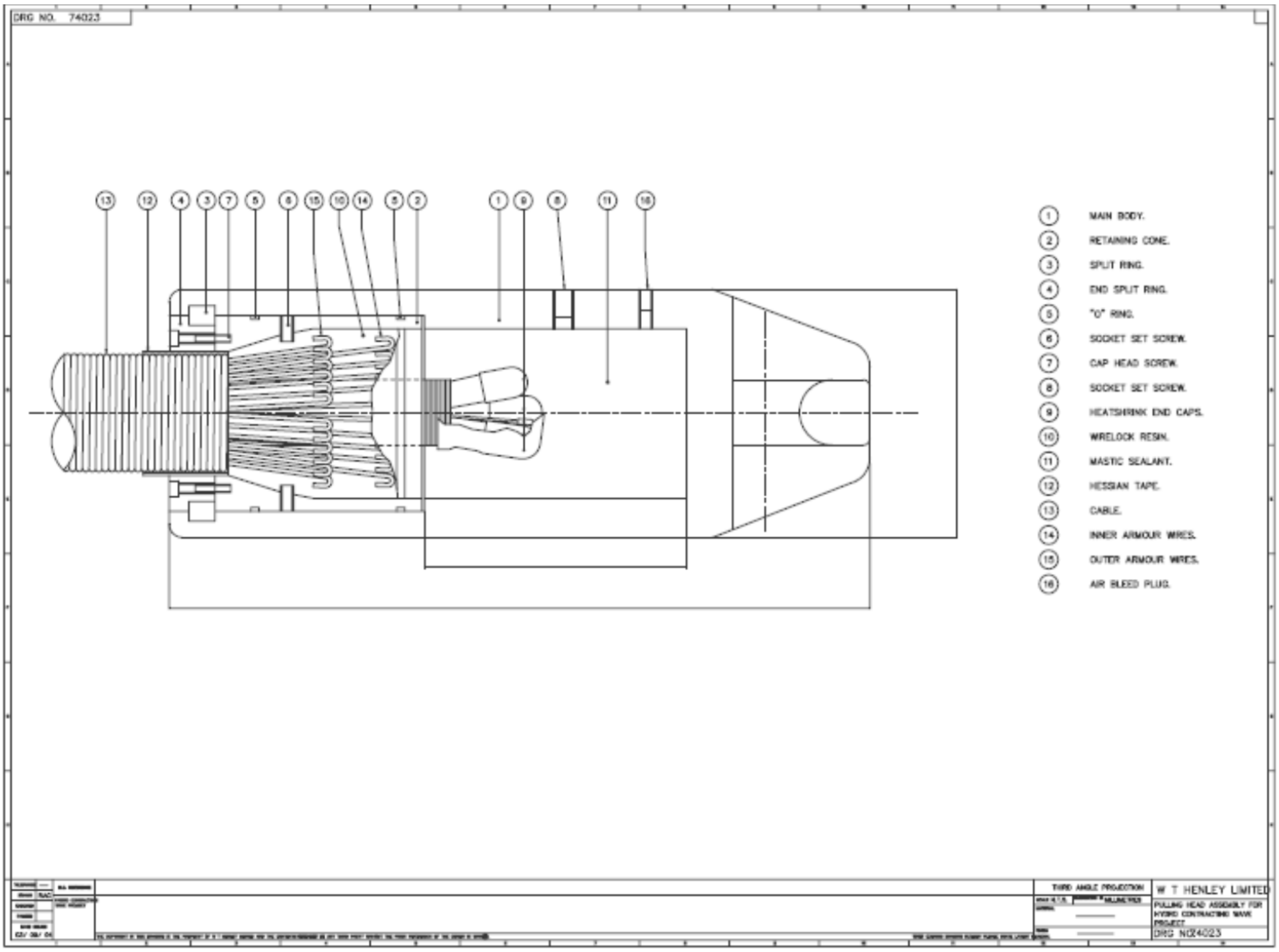


Note that options to be examined include: individual cables to each berth site; two double cables each splitting into two close to the berth sites; one single larger cable with a passive subsea hub to split into four cables closer to the berth sites. The ROM costs of these options have been estimated in a separate cost report.

Appendix 2 - Cable Design Information

The essential principles of cable sizing are summarised in an associated document "Principles of Cable Sizing" from the "CableSizer" website http://www.cablesizer.com/ .
These may be used for general guidance by the Detailed Design Engineer, who should follow the appropriate IEC standards or equivalent for the actual detailed design.

Henley Cable End or Pulling Head



Heatshrink Joints

Information provided below is from one typical vendor of these joints. It should be noted that EMEC does not recommend this vendor above any other and the Detailed Design Engineer should evaluate the most suitable products as part of the design process. Care must be taken to ensure that the joints are suitable for subsea service at the required water depths.

CABLE JOINTS, CABLE TERMINATIONS, CABLE GLANDS, CABLE CLEATS
FEEDER PILLARS, FUSE LINKS, ARC FLASH, CABLE ROLLERS, CUT-OUTS

11KV 33KV CABLE JOINTS & CABLE TERMINATIONS
FURSE EARTHING
www.cablejoints.co.uk
Thorne and Derrick UK
Tel 0044 191 490 1547 Fax 0044 191 477 5371
Tel 0044 117 977 4647 Fax 0044 117 9775582

Heatshrink Joints to suit Low Voltage Cables type Xlpe/Swa/Pvc 0.6/3.3kV

- Meets the jointing requirements of BS 6910 part 1
- Unlimited shelf life
- Slim profile
- Allows for immediate backfill
- No messy toxic resins involved
- Non armoured, lead sheathed and Zero Halogen cable joints are also available on request
- Independent test reports available

Shrink Polymer Systems type SPA heatshrink joint kits are intended for use with Pvc and xlpe cables for voltages up to 3.3kV.

The system comprises of adhesive lined connector insulation tubes, Heavy duty armour cage (copper mesh on the smallest joints), armour support rings, armour clamps and an outer thick wall adhesive lined heatshrink tube.

The single core joints contain a heavy duty Aluminium cage if the cable has aluminium wire armours.

Many thousands of joints are installed worldwide including critical locations such as ministry of defence, department of transport and subsea offshore sites.

HEATSHRINK JOINTS TO SUIT SINGLE CORE XLPE/AWA/PVC

PART NUMBER	CABLE RANGE	VOLTAGE
SPA 50-95-1	50-95mm^2	0.6/3.3kV
SPA 120-185-1	120-185mm^2	0.6/3.3kV
SPA 240-300-1	240-300mm^2	0.6/3.3kV
SPA 400-630-1	400-630mm^2	0.6/3.3kV

HEATSHRINK JOINTS TO SUIT XLPE/SWA/PVC

PART NUMBER	CABLE RANGE	VOLTAGE
SPA 1.5-2.5-	1.5 - 2.5mm^2	600/1000V
SPA 4-6-	4 - 6mm^2	600/1000V
SPA 10-16-	10 - 16mm^2	600/1000V
SPA 25-50-	25 - 50mm^2	0.6/3.3kV
SPA 70-95-	70 - 95mm^2	0.6/3.3kV
SPA 120-185-	120 - 185mm^2	0.6/3.3kV
SPA 240-300-	240 - 300mm^2	0.6/3.3kV

To denote number of cores, add number to end of reference. Example: 12 core 2.5mm^2 = SPA 1.5-2.5-12

Appendix 3 Guide to Thermal De-rating of Cable Currents

ELECTRIC POWER CABLES – WHATEVER HAPPENED TO THE FACTOR OF SAFETY?

By R. (Dick) Hardie Pr Eng, Technical Marketing Manager, Aberdare Cables (Pty) Ltd

INTRODUCTION

Good engineering design has always incorporated factors of safety. For mechanical design, the maximum design load would typically range from 25% of the ultimate tensile strength (U.T.S.) of the material, up to perhaps 70% of the U.T.S. In civil engineering, the Factors of Safety are sometimes even more conservative, for example in the design of concrete structures. A similar philosophy is required when selecting electrical components and equipment in order to design reliably, thus preventing overheating and eventual failure. In so doing, reliable engineering design implies that the equipment will never be called upon to perform beyond its rated capacity.

CURRENT CARRYING CAPACITY OF ELECTRIC CABLE

The ACTUAL current rating of an electric cable is based on the thermal environment in which the cable is installed. In particular, the ambient temperature, depth of burial in the ground, presence and spacing in relation to other cables or other heat sources, and type of soil will have a profound effect on the actual current rating of an electric cable. After the application of applicable derating factors (see tables below) the cable's actual current rating will usually be lower than the standard (un-derated) value quoted by manufacturer's brochures.

To assist in determining the rated capacity of motors, transformers and cables, there are a number of formulae, charts and tables available from the equipment manufacturer. These allow compensation for factors which may enhance or detract from the rated capacity of the equipment. In the case of electric cables, manufacturers quote and publish tables of current ratings which are based on standard conditions of installation, not taking any of the derating factors, mentioned above, into account (ie: un-derated; based on standard conditions of installation).

STANDARD CONDITIONS

	PVC	XLPE
Maximum sustained conductor temperature	70˚	90˚
Ground temperature	25˚	25˚
Ambient air temperature (free Air shaded)	30˚	30˚
Ground thermal resistivity	1,2 K.m/W	1,2 K.m/W
Depth of laying to top of cable or duct (Low Voltage Cable)	500mm	500mm

Table 1 Parameters for standard current rating (as published by manufacturer) for low voltage cable

DERATING FACTORS FOR NON STANDARD CONDITIONS FOR LOW VOLTAGE CABLE(applicable to multi-core cable up to 300mm^2)

Depth of laying(mm)	Direct in ground	In single way ducts
500 800 1000 1250 1500 2000	1,000,970,950,940,930,92	1,000,970,960,950,940,93

Table 2 Derating factors for depth of laying

Thermal Resistivity(K.m/W)	Direct in ground	In single way ducts
1,01,21,52,02,5	1,081,000,930,830,78	1,041,000,960,880,87

Table 3 Derating factors for ground thermal resistivity

No of cables in group	Direct in ground					In Single way ducts			
	Axial spacing (mm)					Axial spacing (mm)			
	Touching	150	300	450	600	Touching	300	450	600
2	0.81	0.87	0.91	0.93	0.94	0.90	0.93	0.95	0.96
3	0.70	0.78	0.84	0.87	0.90	0.82	0.87	0.90	0.93
4	0.63	0.74	0.81	0.86	0.89	0.78	0.85	0.89	0.91
5	0.59	0.70	0.78	0.83	0.87	0.75	0.82	0.87	0.90
6	0.55	0.67	0.76	0.82	0.86	0.72	0.81	0.86	0.90

Table 4 Derating factors for grouping of cables in horizontal formation, at standard depths of laying and in standard soil conditions

Maximum Conductor Temperature (°C)	Ground Temperatures (°C)					
	25	30	35	40	45	50
70 (PVC)	1.00	0.95	0.90	0.85	0.80	0.70
90 (XLPE)	1.00	0.96	0.92	0.88	0.82	0.76

Table 5 Derating factors for ground temperature

Maximum Conductor Temperature	Air Temperatures (°C)			
(°C)	30	35	40	45
70 (PVC)	1.00	0.94	0.87	0.79
90 (XLPE)	1.00	0.95	0.89	0.84

Table 6 Derating factors for air temperature

No. of cables	1	2	3	6	9
Condition	DERATING FACTOR				
Cable touching	1	0.9	0.84	0.80	0.75
Clearance D* between cables	1	0.95	0.9	0.88	0.85

Table 7 Derating factors for grouping of multicore cable installed horizontally in the air

D* is the overall diameter of one cable
Note:
Cables may be grouped in air without derating, provided that the cables are installed on ladders, and that:-
(a) **For horizontal formation**The clearance is greater than 6 x D (or 150mm, whichever is the least) for multi core cables, and 2 x D or 150mm for single core cables.
(b) For vertical formation
(i) The clearance from a vertical wall is greater than 20mm, and
(ii) The vertical clearance between cables is greater than 150mm.
(c) If the number of cables > 4, they are installed in the horizontal plane.

Cross-sectional area ofConductormm²	Correction Factor Solar Radiation	
	1000 W/m²(Coastal)	1250 W/m²(Highveld)
1,5 - 10 16 - 35 50 - 95 120 - 400 240 - 400	0,700,680,650,620,59	0,620,570,530,490,44

Table 8 Derating factors for exposure to solar radiation

Note:
The correction factor applicable to cables exposed to direct solar radiation (ie: exposed to sun) is an extremely important derating factor which is often overlooked.

<u>AN EXAMPLE</u>

Assume that we need to select a Low Voltage PVC insulated electric cable to be installed 1250mm below ground, the cable will be together with 3 other similar cables in the trench, the soil thermal resistivity has been measured, and the sand was found to have a thermal resistivity of 2,5 K.m/W. The slope of the land is north facing, as a result the soil temperature can reach a temperature of 35°C on hot summer days.

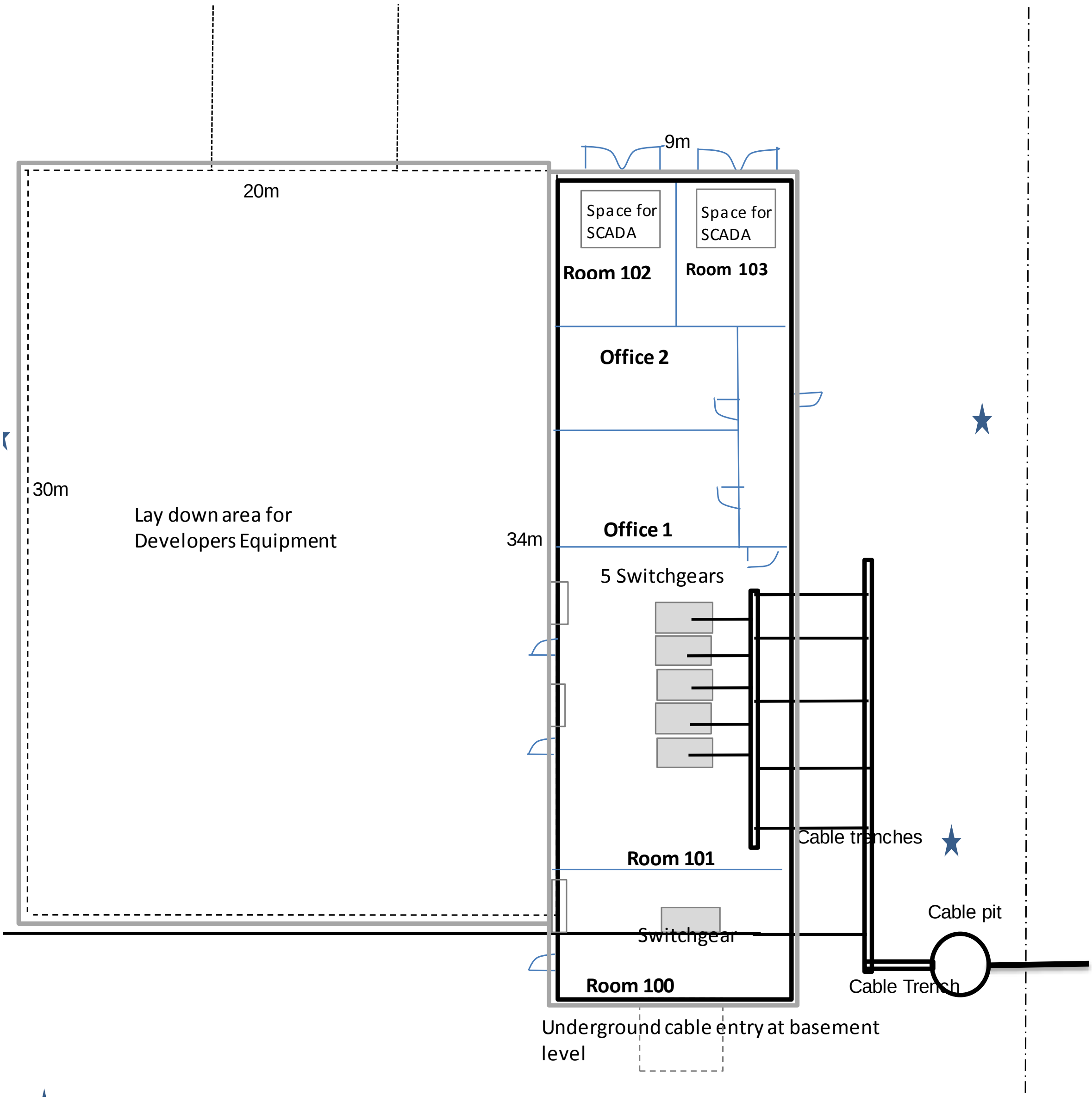
Calculating the overall derating factor
Depth of burial: Table 2.1 yields a derating factor of 0.94
Group derating for 4 cables touching: Table 2.3 yield a derating factor of 0.63
Ground thermal resistances: Table 2.2 yields a derating factor of 0.78
Ground temperature: Table 2.4 yields a derating factor of 0.9
The overall derating factor is 0,94 x 0,63 x 0,78 x 0,9 = 0,41

Now apply this factor to the standard current rating tables as published by electric cable manufacturers.

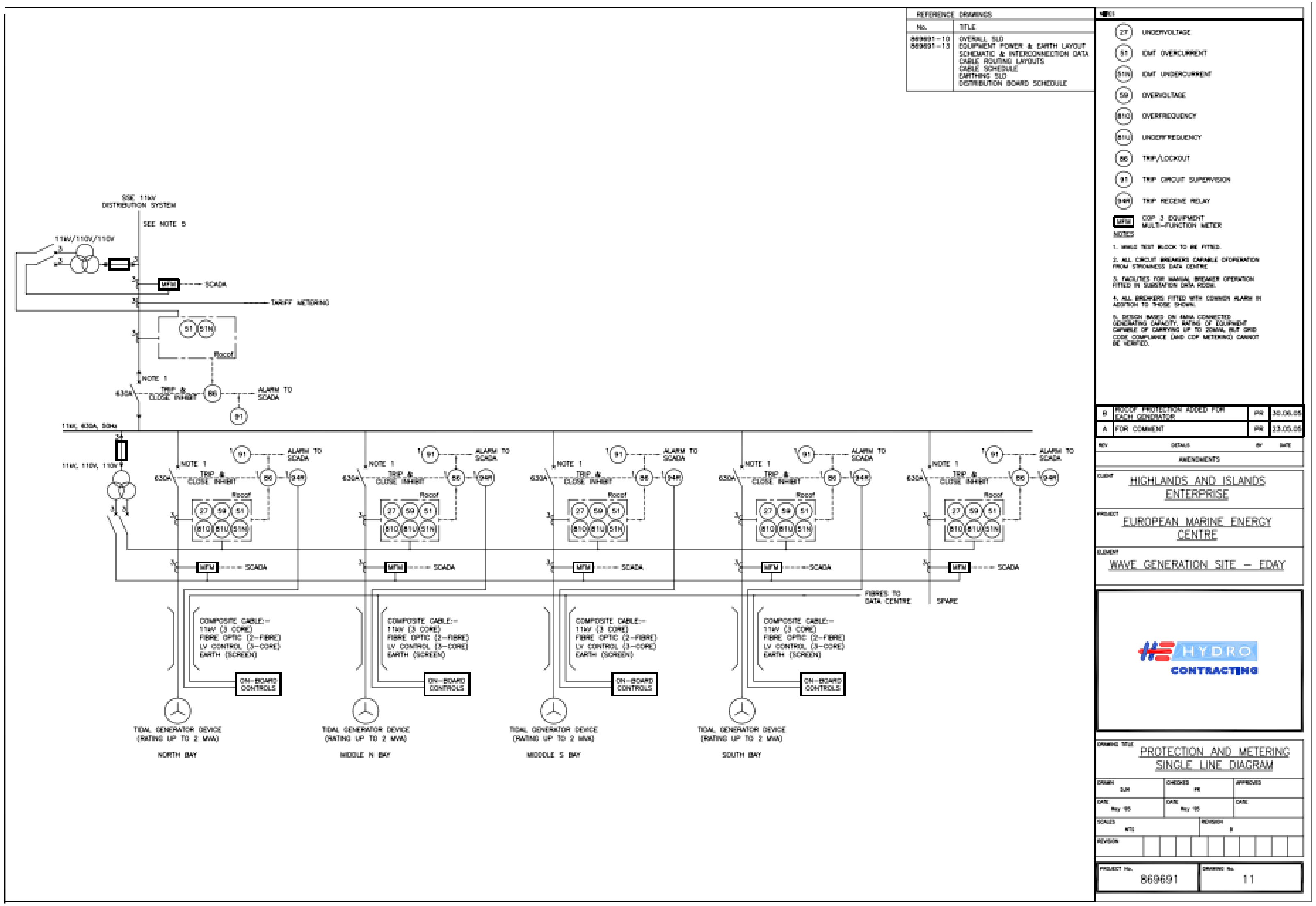
It soon becomes apparent, that a cable with a current rating under "standard" conditions of say 100 Amps, would only have a current rating of 41 Amps under the conditions listed above.In other words, such a cable will be fully loaded when carrying only 41 Amps.

NOTE: This article is a simplified approach to thermal de-rating of current carrying capacity

Appendix 4 – Substation Sketch Plan



Appendix 5 - Substation Single Line Diagram (Example)



Appendix 6 Grid Connection Standard – Contents

Guidelines for Grid Connection of Marine Energy Conversion Systems
The European Marine Energy Centre Ltd 2009, ISBN 978-0-580-65030-7

Introduction
1 Scope
2 Normative references
3 Terms and definitions
4 Electrical parameters
4.1 General
4.2 Frequency
4.3 Voltage range
4.4 Power factor and voltage control
4.5 Power quality
5 Protection
5.1 General
5.2 Protection at the point of connection
5.3 Electrical infrastructure protection
6 Electrical islanding
7 Earthing
7.1 General
7.2 Electrical infrastructure onshore
7.3 Electrical infrastructure offshore
7.4 Marine generators
8 Electromagnetic compatibility
9 Commissioning and Information
9.1 Commissioning
9.2 Information
10 Operation
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Appendix 7 Wave Measurement Instrument

Datawell Directional Waverider MK III

Wave motion sensor based on a stabilised platform, accelerometers, and magnetic compass

- **measures wave height** for wave periods of 1.6 to 30 seconds, accuracy 0.5 % of measured value
- **measures wave direction**
- measures water temperature
- GPS for buoy monitoring and tracking through HF link
- internal logger
- LED flash antenna
- 0.9 m (0.7 m) diameter spherical hull of AISI 316
- optional Cunifer hull, warranted not to corrode
- 3 years (1 year) battery life
- HF transmitter range 50 km over sea

optional Argos module for ocean wide coverage and unlimited range

optional Orbcomm module (incl. GPS module) for two-way communication with buoy, independent of global position

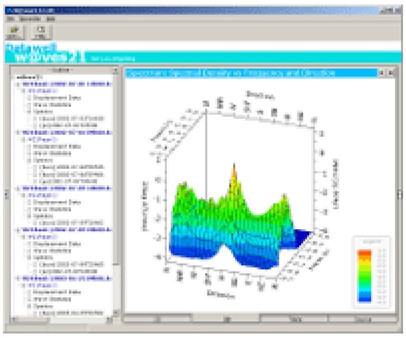
optional Iridium module for ocean wide two-way communication, full spectra every 30 minutes

optional GSM module for data transmission via the GSM network

optional Solar Panel system.

optional hull painting

W@ves21 software



The data acquisition and processing software - w@ves21 - is available now. New features are:

- new file formats available for reading the new data logger and Argos data;
- adding a location ID to the file names;
- right-click a chart to save, print or copy to clipboard;
- acquisition progress indication;
- automatic restart in last mode.

Please contact Datawell if you would like to purchase the w@ves21 v2.1 software or if you want to try the demo version.

W@ves21 is available for download at the Datawell bv website (http://www.datawell.nl/inhoud.php?id=11)

Appendix 8 Tidal Measurement Instruments

The following extract from the Teledyne RD Instruments website serves as an introduction to the Acoustic Doppler Current Profiler (ADCP). A datasheet is contained in the associated documents folder.

Sentinel ADCP

The self-contained Sentinel is Teledyne RD Instruments' most popular and versatile Acoustic Doppler Current Profiler (ADCP) configuration, boasting thousands of units in operation in over 50 countries around the world.
By providing profiling ranges from 1 to 165m, the high-frequency Sentinel ADCP is ideally suited for a wide variety of applications. The Sentinel also offers unbeatable precision, with unmatched low power consumption, allowing you to collect more data over an extended period.
The lightweight and adaptable Sentinel is easily deployed on buoys, boats, or mounted on the seafloor. Real-time data can be transmitted to shore via a cable link or acoustic modem, or data can be stored internally for short or long-term deployments. The Sentinel is easily upgraded to include pressure, bottom tracking, and/or directional wave measurement—for the ultimate data collection solution.

Nortek AS also sell current profilers as this extract from the website shows:

Aquadopp Profiler (datasheet in the associated document folder)

Small and easy-to-use, this current profiler has become a favorite for use in estuaries and shallow coastal water. With the introduction of the new "mid-life" electronics in 2008, it has become shorter by 10 cm, the profiling range has increased, and the power consumption has come down even further.

When the Aquadopp Profiler was introduced in 2000 it represented a completely new generation of current profilers, and even today it remains a cutting edge current profiler. At 2.4 kg, you can carry 2 under each arm, you can deploy it with ease, and you can mount it in places you never dreamed of. The Aquadopp Profiler provides high quality accurate and unbiased data, and it has the classical advantages of acoustic Doppler systems including insensitivity to biofouling and no moving or protruding parts.

The Aquadopp Profiler is an inexpensive tool for shallow water measurements on time scales larger than 1 second. It gives you speed and direction in up to 128 different layers of the water column. The system electronics integrates Doppler velocity with temperature, pressure, tilt, and compass information – all standard with each instrument. The system also has built-in solid state recorder and batteries. State-of-the-art power management and miniaturized electronics combine in a compact single-canister design that is suitable for real-time operation or self-contained deployments.

Appendix 9 Metering Information

Metering Data

The System holds the following metering data:

No.	Description	Logging Interval
1.	Phase Voltage VAB	1 min
2.	Phase Voltage VBC	1 min
3.	Phase Voltage VCA	1 min
4.	Phase Current IA	1 min
5.	Phase Current IB	1 min
6.	Phase Current IC	1 min
7.	Frequency	1 min
8.	A Phase Real Power	1 min
9.	B Phase Real Power	1 min
10.	C Phase Real Power	1 min
11.	A Phase Reactive Power	1 min
12.	B Phase Reactive Power	1 min
13.	C Phase Reactive Power	1 min
14.	A Phase Apparent Power	1 min
15.	B Phase Apparent Power	1 min
16.	C Phase Apparent Power	1 min
17.	Total Cumulative Import Real Power Consumption (kWh)	1 min
18.	Total Cumulative Export Real Power Consumption (kWh)	1 min
19.	Total Cumulative Import Reactive Power Consumption (kWh)	1 min
20.	Total Cumulative Export Reactive Power Consumption (kWh)	1 min
21.	Import Real Power (Max Demand SLR)	1 min
22.	Export Real Power (Max Demand SLR)	1 min
23.	Lagging Reactive Power (Max Demand SLR)	1 min
24.	Leading Reactive Power (Max Demand SLR)	1 min
25.	Positive Apparent Power (Max Demand SLR)	1 min
26.	Negative Apparent Power (Max Demand SLR)	1 min
27.	IA (Max Demand SLR)	1 min
28.	IB (Max Demand SLR)	1 min
29.	IC (Max Demand SLR)	1 min

The data above is typical of the data that should be recorded and stored for measurement purposes.

Elster Meter Information

A1700
Direct Connected or CT Metering

The Power to Change...

A1700 Features

- Accuracy Class 0.2s or 0.5s for CT operation and Class 1 or Class 2 for direct connected, CT or CT/VT operation
- EC Directive 2004/22/EC (MID) Class A, B or C
- Direct connected, CT or CT/VT operated
- Comprehensive tariff structure
- 2 line, multilingual dot matrix display
- Instantaneous instrumentation values
- Instrumentation monitoring
- Instrumentation profiling
- Extensive load profile data
- 2 module slots for extended functionality
- Voltage imbalance detection
- Temperature compensation to maintain RTC accuracy during power outages
- Summation of 5 input values
- 5 co-incident demand values
- 2 kVA registers
- High security design

Options

- Up to 8 outputs
- Interchangeable input/output modules
- Communication modules (RS232 or RS485)
- Communications media (PSTN, GSM, Ethernet, PAKNET)
- Data stream mode communications
- Transformer loss compensation
- Short terminal cover
- Display backlight
- Replaceable RTC backup battery
- Read without power
- Auxiliary a.c. supply

The A1700 offers outstanding measurement and complex tariff capabilities for use in both industrial and commercial direct connected, CT and CT/VT operated applications. The meter can operate as a stand alone unit or as part of a comprehensive metering system.

The A1700 features include a fully programmable customer defined display and an optical port for local communications. Two slots are provided for the addition of an input (or output) and a communications module. Load profile data can be stored for up to 900 days. As an alternative the meter can store 450 days of load profile and 370 days of instrumentation profile data. Data stream mode communications allows up to 90 days of 30 minute profile data to be collected in less than 30 seconds.

Communications modules can be RS232 or RS485.
A range of communications media (PSTN, GSM, Ethernet, PAKNET) plug into a module directly under the meter terminal cover.

An optional input module provides the ideal solution for multi-utility metering. As an alternative, a module with four outputs can be provided to increase the number of outputs to eight.

A module with battery can be provided to read meter data when power has been removed from the meter. Windows™ 'Power Master Unit' software programs or reads the meter data.

The meter can be supplied to meet accuracy Class 0.2s or 0.5s for CT operation and Class 1 or Class 2 for direct connected, CT or CT/VT operation.
EC Directive 2004/22/EC (MID): Class A, B or C.

elster

Measured Quantities

kWh total import/export
kvarh Q1, Q2, Q3, Q4
kVAh (2 calculated values)
3 customer defined registers - summation of up to 5 values
4 inputs for external meters (if fitted)

Tariff Structure

32	Time of use registers
8	Maximum demand registers (block or sliding)
5	Co-incident demands
2	Sliding demands
12	Seasons
24	Season changeover dates
96	Switching times
64	Exclusion dates

The above may vary according to firmware version

Programmable deferred tariff and display

Data Storage

Programmable integration period
Load profile storage or instrumentation quantity
Demand & instrumentation integration periods independently defined

Number of days based on 30 minute period, 1 channel

Measured load profile	Instrumentation profile
900	0
450	0
450	370
0	450

Up to 36 sets of historical data. Fully customer defined, multilingual

Input/Output

Four input module - End of billing, end of integration period, inputs from external meters

Four output relay module - Retransmit pulses from energy registers, customer defined registers or any time-of-use register

Option of three solid-state relays and one 5A relay or four solid-state relays

Communications

Local: IEC 62056-21 (formerly IEC 61107)
Remote: Interchangeable modules (RS232, RS485 or customer specific)

Media : GSM, PSTN, Ethernet, PAKNET

Case

Sealed flip-up lid

- Conceals utility/reset pushbutton
- Provides for customers own information to be securely added to the nameplate
- Allows visual identification of modules fitted

Options

- ANSI communications port
- 9.5 mm terminal block

Technical Data

Current Range	CT operated – 5-6A, 5-10A, 1-2A, 1-1.5A
	Direct connected – 10-100A (widest range)
Voltage Range	57.5 - 240V (3 phase 4 wire)
	100 - 415V (3 phase 3 wire)
Frequency	50Hz or 60Hz
Burden	
Voltage Circuits (230V)	Single element - 1.92W, 4.17VA
	Two/three element - 1.10W, 2.45VA
Current Circuits	CT operated – 0.12VA @ 5A/phase, 0.02VA @ 1A/phase
	Direct connected – 0.2VA @ 100A/phase
Insulation	4kV RMS 50Hz
Impulse Withstand	12kV 1.2/50us 50ohm source
Display	2 line, 16 character dot matrix
	liquid crystal display
	8mm digits
Baud Rates	1200, 2400, 4800, 9600
Product Life	15 years
Certified Product Life	10 years (by OFGEM)
Temperature	-25° to + 55° C (Operational range)
	-25° to +70° C (Optional operating range)
	-25° to + 70° C (Storage)
Humidity	Annual mean 75% (for 30 days spread over one year, 95%)
Pulse Width / Value	Programmable
Relay Specification	240V a.c.
	100mA
	1 x 5A relay (option, module only)
Dimensions	279mm (high) x 170mm (wide) x 81mm (deep)
Weight	1300 grams
Specifications	IEC 62052-11 and IEC 62053 -21, -22, -23
	EC Directive 2004/22/EC (MID) Class A, B or C
Case	IP53 to IEC 60529:1989

Elster Metering Systems
Tollgate Business Park,
Paton Drive
Beaconside
Stafford, Staffordshire, ST16 3EF
United Kingdom
Tel: +44 (0) 1785 275200
Fax: +44 (0) 1785 275300
www.elstermetering.com

A1700 CT & DC 3D 01.2009

Appendix 10 SCADA System Details (Example)

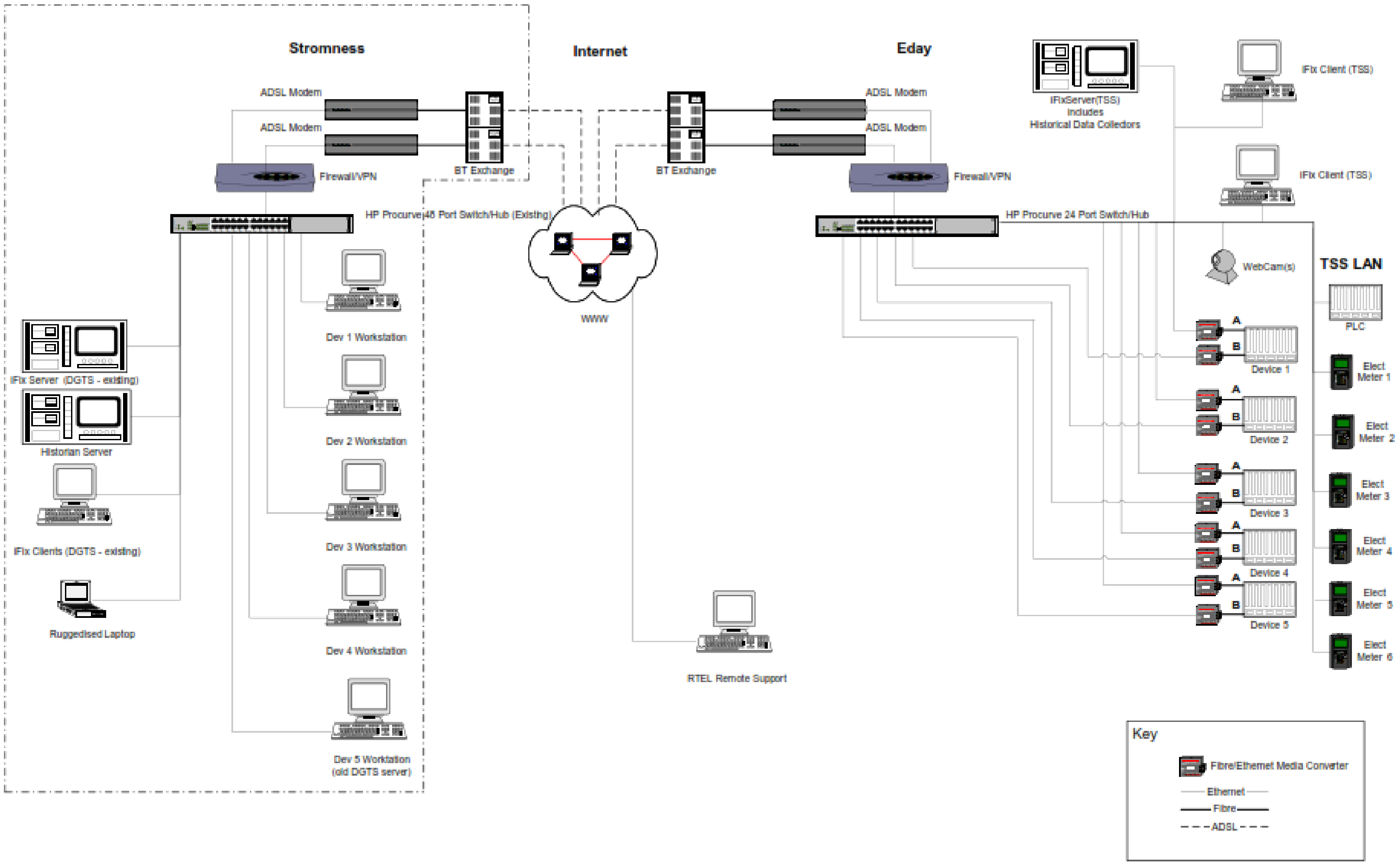


Fig. A.1 TSS System Architecture

Typical Contents for a SCADA Functional Design Specification (FDS)
SECTION 1

Introduction
1.1 Project Background
1.2 Purpose of Document
1.3 Structure of Document
1.4 Glossary of Terms
1.5 References
SECTION 2
System Architecture
2.1 Overview
2.2 Data Gathering and Transmission System, Location A
2.3 Area Supervision System, Location B
2.4 Hardware
2.5 Archiving
SECTION 3
System Interfaces
3.1 Tidal Stream Devices
3.2 Tidal Flow Data
3.3 Tidal Power Quality Data
3.4 Wave Devices
3.5 Wave Data
3.6 Wind Devices
3.7 Wind Data
3.8 Solar Devices
3.9 Solar Data
3.10 Metering
3.11 Switchgear Controls, Status and Alarms
3.12 Alarming
SECTION 4
SCADA Application software
4.1 Introduction
4.2 Design Objectives
4.3 Design Standards and Policies
4.4 Displays
4.5 Historical Data
4.6 Reporting
SECTION 5
Testing Considerations
5.1 Pre FAT and FAT
5.2 SAT
5.3 Commissioning
Appendix A
System Architecture
Appendix B
PLC Inputs and Outputs

Appendix C
Metering Data
Appendix D
Alarm List
Operational Information

Alarm List

The system maintains the following alarms:

	Category			
Alarm Description	**A**	**B**	**C**	**Maintenance Action Text**
Switchboard G59	✓			Initiate 4 hour call-out + manual reference
Incomer Overcurrent/Earth Fault Trip	✓			Initiate 4 hour call-out + manual reference
Incomer Trip Circuit Supervision		✓		Fault in control system circuit initiate 8 hour call out or check in new working day + manual reference
Incomer Loss of closing voltage		✓		Initiate 8 hour call-out + manual reference
Incomer 80% rating exceeded		✓		Initiate 8 hour call-out + manual reference
Device A CB Overcurrent/Earth Fault Trip	✓			Initiate 4 hour call-out + manual reference
Device A CB On-board trip	✓			Call Developer - await response + manual reference
Device A CB Trip Circuit Supervision		✓		Fault in control system circuit initiate 8 hour call out or check in new working day + manual reference
Device A CB Loss of closing voltage		✓		Initiate 8 hour call-out + manual reference
Device A CB 80% rating exceeded		✓		Initiate 8 hour call-out + manual reference
Device B CB Overcurrent/Earth Fault Trip	✓			Initiate 4 hour call-out + manual reference
Device B CB On-board trip	✓			Call Developer - await response + manual reference
Device B CB Trip Circuit Supervision		✓		Fault in control system circuit initiate 8 hour call out or check in new working day + manual reference
Device B CB Loss of closing voltage		✓		Initiate 8 hour call-out + manual reference
Device B CB 80% rating exceeded		✓		Initiate 8 hour call-out + manual reference
Device C CB Overcurrent/Earth Fault Trip	✓			Initiate 4 hour call-out + manual reference
Device C CB On-board trip	✓			Call Developer - await response + manual reference

	Category			
Alarm Description	A	B	C	Maintenance Action Text
Device C CB Trip Circuit Supervision		✓		Fault in control system circuit initiate 8 hour call out or check in new working day + manual reference
Device C CB Loss of closing voltage		✓		Initiate 8 hour call-out + manual reference
Device C CB 80% rating exceeded		✓		Initiate 8 hour call-out + manual reference
Device D CB Overcurrent/Earth Fault Trip	✓			Initiate 4 hour call-out + manual reference
Device D CB On-board trip	✓			Call Developer - await response + manual reference
Device D CB Trip Circuit Supervision		✓		Fault in control system circuit initiate 8 hour call out or check in new working day + manual reference
Device D CB Loss of closing voltage		✓		Initiate 8 hour call-out + manual reference
Device D CB 80% rating exceeded		✓		Initiate 8 hour call-out + manual reference
Option - Device E CB Overcurrent/Earth Fault Trip	✓			**Initiate 4 hour call-out + manual reference**
Option - Device E CB On-board trip	✓			**Call Developer - await response + manual reference**
Option - Device E CB Trip Circuit Supervision		✓		**Fault in control system circuit initiate 8 hour call out or check in new working day + manual reference**
Option - Device E CB Loss of closing voltage		✓		**Initiate 8 hour call-out + manual reference**
Option - Device E CB 80% rating exceeded		✓		**Initiate 8 hour call-out + manual reference**
Substation Alarms				
Substation Aux. Supply Failure		✓		If stand-by Generator off, initiate 8 hour call out + manual reference
Diesel Generator Alarm	✓			Initiate 4 hour call-out + manual reference
UPS Fault		✓		Initiate 8 hour call-out + manual reference
Diesel Room Extract Fan Failure	✓			Initiate 4 hour call-out + manual reference
Switchgear Trip/Close Supply Fault		✓		Initiate 8 hour call-out + manual reference
Substation Security	✓			

	Category			
Alarm Description	**A**	**B**	**C**	**Maintenance Action Text**
Miscellaneous				
Developer A communications failure		✓		Initiate 8 hour call-out, advise Developer + manual reference
Developer B communications failure		✓		Initiate 8 hour call-out, advise Developer + manual reference
Developer C communications failure		✓		Initiate 8 hour call-out, advise Developer + manual reference
Developer D communications failure		✓		Initiate 8 hour call-out, advise Developer + manual reference
Option - Developer E communications failure		✓		**Initiate 8 hour call-out, advise Developer + manual reference**

The alarm list reproduced above is for a scheme with 4 test berths, with an option to expand to a fifth. The table lists the typical alarms that a Facility Operator may wish to see and categorises them into three groups A, B and C which are of decreasing urgency and importance. Also identified are the actions that would be required if each alarm was received at any time of day or night.

The alarm list will form the basis of detailed instructions to any Duty Manager who may be responsible for the Facility operation outside of working hours. The Operator would draw up instructions to personnel with responsibility for staffing the round-the-clock rota to guide them in taking essential actions and decisions.

Note that this alarm list is indicative only, it is not a design for an alarm system but it does provide broad guidance to the Detailed Design Engineer who will carry out the design work.

Appendix 11 Axis Network Camera Series Datasheet

DATASHEET

AXIS M10 Network Camera Series

Smallest and smartest network cameras from the market leader.

- > Functional and smart design
- > Multiple H.264 streams
- > Easy and flexible installation
- > PIR sensor and illumination LED
- > Microphone and speaker
- > I/O ports

AXIS M10 Series offers small and smart cameras, ideal for securing locations such as small businesses, boutiques, restaurants, hotels or residences. These intuitive and dependable cameras offer best-in-class image quality and professional monitoring capabilities.

AXIS M10 Network Cameras with their functional and smart design offer a high quality yet affordable video surveillance solution. Using progressive scan technology, the cameras provide VGA or HDTV (AXIS M1054) images of moving objects without motion blur.

Multiple H.264 and Motion JPEG streams can be provided simultaneously, individually optimized for different quality needs and bandwidth constraints. AXIS M1011, AXIS M1011-W and AXIS M1031-W additionally support MPEG-4 Part 2 for backward compatibility.

AXIS M10 Series is designed for easy and flexible installation. AXIS M1011-W and AXIS M1031-W offer the choice of either a wireless or a wired connection to the network, and AXIS M1054 can be powered either over Ethernet or by power supply.

AXIS M1031-W and AXIS M1054 feature an integrated PIR sensor for detecting movement even in the dark, and a white LED for illuminating the scene at an event. AXIS M1054 additionally supports one input and one output port for connecting external devices.

AXIS M1031-W and AXIS M1054 provide two-way audio support with built-in microphone and speaker, allowing remote listening in on an area, as well as communication with individuals directly or using uploaded or recorded audio clips.

HDTV NETWORK VIDEO

ONVIF

www.axis.com

Technical Specifications – AXIS M10 Network Camera Series

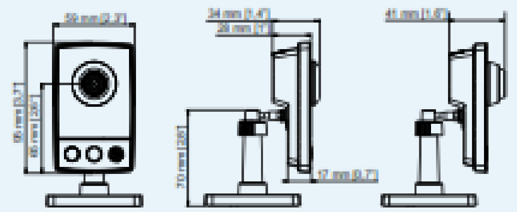
Camera	
Models	AXIS M1011: Wired interface AXIS M1011–W: Wired and wireless interface AXIS M1031–W: Wired and wireless interface, PIR sensor, illumination LED, audio AXIS M1054: Power over Ethernet, PIR sensor, illumination LED, audio, I/O ports
Image sensor	AXIS M1011/M1011–W/M1031–W: 1/4" progressive scan RGB CMOS, AXIS M1054: 1/4" progressive scan RGB CMOS
Lens	AXIS M1011/M1011–W/M1031–W: 4.4 mm: 47° view*, F2.0, fixed iris, fixed focus AXIS M1054: 2.9 mm: 84° view*, F2.0, fixed iris, fixed focus *horizontal angle of view
Light sensitivity	AXIS M1011/M1011–W/M1031–W: 1-10000 lux, F2.0 AXIS M1054: 1.2 – 100000 lux, F2.0 AXIS M1031–W/M1054: 0 lux with illumination LED on
Shutter time	AXIS M1011/M1011–W/M1031–W: 1/5000 s to 1/4 s AXIS M1054: 1/24500 s to 1/6 s
Pan/Tilt/Zoom	AXIS M1054: Digital PTZ, preset positions, guard tour
Video	
Video compression	H.264 (MPEG–4 Part 10/AVC), Motion JPEG AXIS M1011/M1011–W/M1031–W: MPEG–4 Part 2 (ISO/IEC 14496–2)
Resolutions	AXIS M1011/M1011–W/M1031–W: 640x480 to 160x120 AXIS M1054: 1280x800 to 160x90
Frame rate	**H.264**: 30 fps in all resolutions **Motion JPEG**: 30 fps in all resolutions AXIS M1011/M1011–W/M1031–W, **MPEG–4 Part 2**: 30 fps in all resolutions
Video streaming	Multiple, individually configurable streams in H.264 and Motion JPEG, as well as MPEG–4 Part 2 with AXIS M1011/ M1011–W/M1031–W Controllable frame rate and bandwidth VBR/CBR H.264, MPEG–4 Part 2
Image settings	Compression, color, brightness, sharpness, contrast, white balance, exposure control, exposure zones, backlight compensation, fine tuning of behavior at low light, rotation Text and image overlay, Privacy mask AXIS M1054: Mirroring
Audio (AXIS M1031–W & AXIS M1054)	
Audio streaming	Two–way
Audio compression	AAC–LC 8/16 kHz, G.711 PCM 8kHz, G.726 ADPCM 8 kHz Configurable bit rate
Audio in/out	Built–in microphone and speaker
Network	
Wireless interface	AXIS M1011–W/M1031–W: IEEE 802.11g/b Invisibly integrated antenna
Security	Password protection, IP address filtering, HTTPS** encryption, digest authentication, user access log AXIS M1011–W/M1031–W: WEP 64/128 bit, WPA/WPA2–PSK
Supported protocols	IPv4/v6, HTTP, HTTPS**, QoS Layer 3 DiffServ, FTP, SMTP, Bonjour, UPnP, SNMPv1/v2c/v3(MIB–II), DNS, DynDNS, NTP, RTSP, RTP, TCP, UDP, IGMP, RTCP, ICMP, DHCP, ARP, SOCKS

***This product includes software developed by the OpenSSL Project for use in the OpenSSL Toolkit. (www.openssl.org)*

More information is available at www.axis.com

System integration	
Application Programming Interface	Open API for software integration, including the ONVIF specification available at www.onvif.org, as well as VAPIX® from Axis Communications, specifications available at www.axis.com Support for AXIS Video Hosting System (AVHS) with One-Click Camera connection
Intelligent video	Video motion detection, active tampering alarm AXIS M1031–W/M1054: Audio detection
Alarm triggers	Intelligent video AXIS M1031–W/M1054: PIR sensor AXIS M1054: PIR sensor, external input
Alarm events	File upload via FTP, HTTP and email Notification via email, HTTP and TCP AXIS M1031–W/M1054: Activation of illumination LED, audio clip playback, AXIS M1054: external output activation
Video buffer	AXIS M1011/M1011–W/M1031–W: 16 MB pre- and post alarm AXIS M1054: 25 MB pre- and post alarm
General	
Processor and memory	AXIS M1011/M1011–W/M1031–W: ARTPEC-B, 64 MB RAM, 32 MB Flash, AXIS M1054: ARTPEC-3, 128 MB RAM, 128 MB Flash
Power	4.9 – 5.1 V DC, max. 6.5 W AXIS M1054: Power over Ethernet IEEE 802.3af Class 2 (max. 6.49W)
Connectors	DC jack, RJ–45 10BASE–T/100BASE–TX AXIS M1054: 1 alarm input and 1 output
PIR sensor	AXIS M1031–W/M1054: Passive infrared (PIR) motion sensor with configurable sensitivity. Max range: 6 m
Illumination LED	AXIS M1031–W/M1054: White illumination LED: 1 W
Operating conditions	Humidity 20 – 80% RH (non-condensing) AXIS M1011/M1011–W/M1031–W: 0 – 50 °C (32 – 122 °F) AXIS M1054: 0 – 40 °C (32 – 113 °F)
Approvals	AXIS M1011: EN 55022 Class B, EN 55024, EN 61000–3–2, EN 61000–3–3, EN 60950–1, FCC Part 15 Subpart B Class B, VCCI Class B, ICES–003 Class B, C-tick AXIS M1011–W/M1031–W: EN301489–1, EN301489–17, EN300328, EN 60950–1, FCC Part 15 Subpart B and C Class B, RSS-210, C-TICK, TELEC, KCC, SRRC AXIS M1054: EN 55022 Class B, EN 61000–3–2, EN 61000–3–3, EN 55024, FCC Part 15 Subpart B Class B, ICES–003 Class B, VCCI Class B, C-tick AS/NZS CISPR 22, KCC Class B, EN 60950–1 Power supply: EN 60950–1, cCSAus
Weight	AXIS M1011: 94 g (0.21 lb), AXIS M1011–W: 94 g (0.21 lb) AXIS M1031–W: 100 g (0.22 lb), AXIS M1054: 160 g (0.35 lb)
Included accessories	Power supply, stand and clamp, Installation Guide, CD with installation tools, recording software and User's Manual, Windows decoder 1–user license AXIS M1054: Extension for stand: 100 mm (4.0")
Video management software (not incl.)	AXIS Camera Station – Video management software for viewing and recording up to 50 cameras. For more software application via partners, see www.axis.com/products/video/software/

Dimensions



All cameras — AXIS M1011/M1011–W/M1031–W — AXIS M1054

AXIS COMMUNICATIONS

Appendix 12 Eaton UPS

Eaton 9130 UPS

700 – 6000 VA

Multilingual LCD

Advanced power protection for:

- IT and networking environments
- Servers, networking gear
- Telecommunications, VoIP, security systems
- Medical systems
- Diagnostics and medical screening
- Patient record archives
- Manufacturing systems
- Chip fabrication
- Pharmaceutical production
- Chemical processing

Double conversion UPS

Highest power performance

- Double conversion topology. The 9130 constantly monitors power conditions and regulates voltage and frequency. Even when presented with the most severe power problems, UPS's output remains within 3% of nominal voltage.
- More real power. High 0.9 output power factor enables the 9130 to provide its full power capability to modern IT equipment.
- Highest efficiency to reduce utility and cooling spending. The 9130 can provide up to 95% efficiency in online double conversion mode and up to 98% in high-efficiency mode.

Unmatched reliability

- The internal bypass allows service continuity in case of internal fault, a maintenance bypass is also available (as option) for easy replacement of the UPS without powering down critical systems.
- Stronger, longer battery life. Eaton ABM® battery management technology uses an innovative three-stage charging technique, that only recharges the battery when necessary, so the battery experiences less corrosion and service life is prolonged by up to 50%.
- Batteries can be hot-swapped without ever having to shut down connected equipment.
- Possibility to add more runtime at any time with up to four external hot-swappable battery modules to run systems for hours if necessary.
- Enables prolonged runtime of essential equipment during power outages by allowing for orderly, remote shutdown of non-critical systems and processes thanks to a capability to control load segments (available up to 3kVA).

Outstanding versatility

- One platform, two factors, dozens of choices. Up to 3000 VA of UPS power is packed into only 2U of rack space. The tower option is about the size of a modem, compact PC.
- Enhanced configuration capability through easily navigated multilingual graphical display.
- Remote monitoring. The 9130 comes complete with the Eaton Software Suite CD including SNMP-compatible power management software providing control and visibility over all your UPS systems.
- Connectivity options are available for almost any network environment.

EATON
Powering Business Worldwide

1. Multilingual graphical LCD display
2. Panel for replacing batteries
3. 1 USB port + 1 serial port
4. 1 Relay Output + 1 EPO connector
5. EBM battery unit connector
6. Load segments
7. Communication card slot

TECHNICAL SPECIFICATIONS

General	
User interface	Graphical LCD with blue backlight and text in English, French, German, Russian and Spanish
LEDs	Four status-indicating LEDs
Topology	True online, double-conversion
Diagnostics	Full system self-test
UPS bypass	Automatic bypass
Rail kit	Included with all rackmount units
Electrical Input	
Nominal voltage	220–240V
Voltage range	up to 120–276 VAC (depending on load level)
Frequency range	40–70 Hz (50/60 Hz)
Electrical Output	
Power factor	0.9
Voltage	±3 % of nominal regulation (on utility and battery)
Frequency regulation	±3 Hz online
Load crest factor	3 to 1

Communications	
Ports	RS-232 and USB HID port as standard
Relay output	Common alarm standard
Optional communication cards (BD/MS Slot)	SNMP/Web card for monitoring in SNMP-based networks, monitoring through Web browser interface. Relay card for integration to industrial environment and BMS, remote shutdown for IBM AS/400 systems
Environmental	
Safety and EMC markings	IEC/EN 62040-1-1, IEC/EN 62040-2, CE marking
Audible noise	<50 dB
Ambient operating	0°C to +40°C
Storage temperature	-20°C to +40°C with batteries and -25°C to +55°C without batteries
Relative humidity	5–90% non-condensing

Description	Part number	Rating (VA/Watts)	Input connection	Output receptacles	Dimensions H x W x D, mm	Weight, kg
Tower Models						
PW9130i700T	103006433-6591	700/630	C14	(6) C13	230 x 160 x 350	12.2
PW9130i1000T-XL	103006434-6591	1000/900	C14	(6) C13	230 x 160 x 380	14.5
PW9130i1500T-XL	103006435-6591	1500/1350	C14	(6) C13	230 x 160 x 430	19.0
PW9130i2000T-XL	103006436-6591	2000/1800	C14	(8) C13, (1) C19	325 x 214 x 410	34.5
PW9130i3000T-XL	103006437-6591	3000/2700	C20	(8) C13, (1) C19	325 x 214 x 410	34.5
PW9130i5000T-XL	103007841-6591	5000/4500	Hardwire	Hardwire	574 x 244 x 542	75.5
PW9130i6000T-XL	103007842-6591	6000/5400	Hardwire	Hardwire	574 x 244 x 542	75.5
Tower Extended Battery Modules						
PW9130N1000T-EBM	103006438-6591	NA	NA	NA	230 x 160 x 380	18.5
PW9130N1500T-EBM	103006439-6591	NA	NA	NA	230 x 160 x 430	24.3
PW9130N3000T-EBM	103006440-6591	NA	NA	NA	325 x 214 x 410	50.0
PW9130N6000T-EBM	103007843-6591	NA	NA	NA	574 x 244 x 542	111
Rack Models						
PW9130i1000R-XL2U	103006455-6591	1000/900	C14	(6) C13	86.5 x 438 x 450	16
PW9130i1500R-XL2U	103006456-6591	1500/1350	C14	(6) C13	86.5 x 438 x 450	19
PW9130i2000R-XL2U	103006457-6591	2000/1800	C14	(8) C13, (1) C19	86.5 x 438 x 600	29
PW9130i3000R-XL2U	103006463-6591	3000/2700	C20	(8) C13, (1) C19	86.5 x 438 x 600	29.5
Rack Extended Battery Modules						
PW9130N1000R-EBM2U	103006458-6591	NA	NA	NA	86.5 x 438 x 450	22.1
PW9130N1500R-EBM2U	103006459-6591	NA	NA	NA	86.5 x 438 x 450	28.1
PW9130N3000R-EBM2U	103006460-6591	NA	NA	NA	86.5 x 438 x 600	41.1

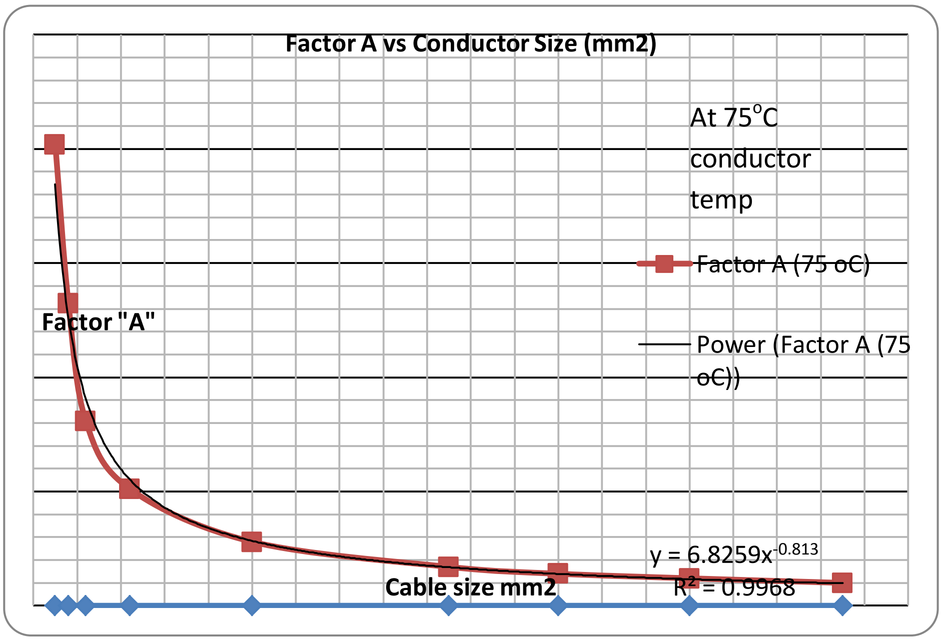
	Internal batteries		+1 EBM		+2 EBMs		+3 EBMs		+4 EBMs	
BATTERY RUNTIMES*	75% Load	50% Load	75% Load	50% Load	75% Load	50% Load	75% Load	50% Load	75% Load	50% Load
Rack models										
PW9130i1000R-XL2U	13	22	55	82	103	186	151	250	223	312
PW9130i1500R-XL2U	11	18	47	81	83	143	126	208	195	262
PW9130i2000R-XL2U	13	24	63	95	118	190	170	242	221	345
PW9130i3000R-XL2U	8	14	34	62	70	92	96	156	130	211
Tower models										
PW9130i700T-XL	12	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PW9130i1000T-XL	13	22	55	82	103	186	151	250	223	312
PW9130i1500T-XL	11	18	47	81	83	143	126	208	195	262
PW9130i2000T-XL	21	34	81	130	145	198	184	293	248	431
PW9130i3000T-XL	12	20	49	79	90	143	134	180	165	240
PW9130i5000T-XL	20	34	81	136	153	232	217	328	273	477
PW9130i6000T-XL	16	27	66	107	120	194	178	267	231	372

* Runtimes are shown at a 0.7 power factor. Backup times are approximate and may vary with equipment, configuration, battery age, temperature, etc.

www.eaton.com/powerquality

Appendix 13 Assessment in Losses in Cables

EMEC have used the method following to calculate power losses in cables. The Tyco sheet (014-Drop-0901) gives a calculation method for voltage drop.
To determine factor A, at 0.95 PF Table 4 was extrapolated as shown:



For a cable of 11.13 km length, this gives a voltage drop of 81.6 volts at 92 Amps current and 15°C (corresponds to 1MW power), then the power loss from the equation shown below at point 1 is then 81.6*92/1000 = 7.53kW or 0.75%.

Points 2 to 5 below show a sample calculation for a 50mm2 cable of around 2.7km length – typical .

Rationale for TYCO method: see doc

1 Using Formula: $\frac{\text{Run length (ft) x Conductor current (amps) x Factor "A"}}{1000}$ = Voltage drop

2 Factor A interpolated for table 4 of 14-DROP-0901 using table 2, where A reduces by a ratio of **0.519** from AWG 4 to AWG 1
This is done as no value for AWG 1 is given in table 4, so the AWG 1 value is inferred as the same ratio as that given in table 2.

3 Applying 0.519 to A in table 4 for AWG 4 (3 conductor cable at 75 Deg C) gives: 0.512 x 0.519 = **0.2657**

4 Reducing to temperature of 15 Deg C at "delta A" = 0.0016/Deg C gives: A= **0.170** Some 30% greater than the pure ohmic resistance
NB - The Difference between Factor A at 75 Deg C for a triple conductor - table 4 (0.512) and at 90 Deg C - table 3 (0.536) is) 0.024 for the 15 deg interval hence 0.024/15 = 0.0016 per degree

5 Expressing Power loss (kW) results as percentage of total power gives the range between 0.12% and 0.75% depending on cable length

Table showing Properties of stranded bare copper conductors size AWG 1

Size AWG/MCM	Stranding	Nominal O.D. of Strand	Approx. O.D. (in.)	Weight Lbs/Mft	OHMS/ Resistance Per Mft
1	19/.0664	0.0664	0.332	266	0.13
1	133/.0251	0.0251	0.38	264	0.132
1	259/.0180	0.018	0.378	265.24	0.121
1	836/30	0.001	0.365	266	0.133
1	2107/34	0.0063	0.376	268	0.134

Source: Industrial Electric Technical Guide - Bare Stranded Copper
http://www.iewc.com/Tech7.htm

Matched to cable spec.EMEC Dwg No CAB 2310
50mm2 plain stranded copper diam 8.44 mm

Using the method of estimating resistance in IEC 60287 for three core cable (at high current), the AC resistance for this cable approximates to

36.8% more than the dc ohmic resistance. Given that these currents are not high - the proximity factor should be less than suggested in the paper by General cable of New Zealand No 10.3.2.1 "AC Resistance Skin and Proximity Effect"

This method would increase the Factor "A" by a little over 5% - explained by the modest current regime considered here. The method is deemed fit for purpose to demonstrate that "Copper Loss" is a low percentage of power measured even at very modest currents

JWG/Copper loss/27-06-05

COMPREHENSIVE VOLTAGE DROP CALCULATIONS

Voltage drop calculations are best made using the information provided in Tables 1 through 4. These tables give a multiplying factor, Factor A, expressed in units of volts per ampere per one thousand feet of conductor.

For current loads at or above 75% of the conductor's rated ampacity, use the data presented in either of Tables 1 or 3 as applicable. Values are based on an assumed conductor temperature of 90°C. For loads less than 75% of the conductor's rated ampacity, use the data presented in either of Tables 2 or 4, again as applicable. Here, values are based on an assumed conductor temperature of 75°C.

Tables 1 and 2 have been derived on the basis of cables installed as per Pyrotenax recommendations for single conductor, three phase circuits, that is, in trifoil bundles containing one conductor from each phase. However, the factors given are sufficiently accurate when applied to other installation configurations that they can be used for the purposes of voltage drop estimation without correction. Other configurations may include:

1) Three phase, four wire installations in which the neutral conductor is included in the bundle of phase conductors.
2) Three phase installations employing three or four wires in which the conductors are laid flat beneath a common restraining clip.
3) Single phase, two or three wire installations in which the conductors are installed with sheaths in contact in a single bundle.

Tables 3 and 4 are applicable to three conductor cable installations.

Once the proper Factor A has been selected from the tables, the voltage drop is easily calculated with the following equations:

$$\text{Voltage drop } \textit{(in volts)} = \frac{\text{Run Length } \textit{(ft)} \times \text{Conductor Current } \textit{(amps)} \times \text{Factor A } \textit{(from table)}}{1000}$$

$$\text{Voltage drop } \textit{(in percent)} = \frac{\text{Voltage Drop } \textit{(volts)} \times 100}{\text{Circuit Voltage } \textit{(volts)}}$$

Note that these calculated voltage drops represent the line to line voltage drop in a three phase system. To estimate the single phase voltage drop, simply multiply the three phase line to line voltage drop by 1.16. In those rare instances in which the line to neutral voltage drop in a three phase system is required, multiply the line to line voltage drop by 0.58.

EXAMPLE 1

Given:
- Load Current = 100 amperes
- Cable Reference = 1/1/0-512, #1/0
- System Voltage = 600 volt, 3 phase
- Power Factor = 0.85
- Run Length from source to load = 500 feet
- Cables installed in 3 phase, 3 wire trifoil bundle.

Estimate:
- Line to line voltage drop
- Percentage drop

Rated ampacity 1/1/0-512, #1/0 single conductor cable is 260 amperes (NEC); 245A (CEC)
Ratio of load to rated ampacity is 100/245=0.408 therefore use table based on 75°C conductor temperature.

From Table 2 for single conductor installations at 75°C.

Factor A = 0.209 volts per ampere per thousand feet

$$\text{Voltage Drop} = \frac{500 \times 100 \times 0.209}{1000}$$

$$= 10.4 \text{ volts}$$

$$\text{Percent Voltage Drop} = \frac{10.4 \times 100}{600}$$

$$= 1.7\%$$

TABLE 1 - voltage drop Factor A - for single conductor cable in trifoil - 90°C conductor temperature

Cable Reference	Conductor Size AWG / MCM	Lagging Power Factor in Percent 100	95	90	85	80	75
1/6-340	6	0.874	0.851	0.816	0.778	0.740	0.700
1/4-402	4	0.550	0.542	0.523	0.501	0.479	0.455
1/3-449	3	0.438	0.435	0.421	0.405	0.388	0.370
1/2-449	2	0.347	0.349	0.339	0.327	0.314	0.301
1/1-496	1	0.276	0.281	0.274	0.266	0.256	0.246
1/1/0-512	1/0	0.220	0.227	0.223	0.218	0.211	0.203
1/2/0-580	2/0	0.175	0.184	0.182	0.179	0.174	0.169
1/3/0-621	3/0	0.141	0.151	0.151	0.149	0.146	0.142
1/4/0-684	4/0	0.114	0.125	0.126	0.125	0.123	0.121
1/250-746	250	0.097	0.109	0.111	0.111	0.110	0.108
1/350-834	350	0.074	0.086	0.089	0.090	0.090	0.089
1/500-1000	500	0.056	0.069	0.072	0.074	0.075	0.076

TABLE 2 - voltage drop Factor A - for single conductor cable in trifoil - 75°C conductor temperature

Cable Reference	Conductor Size AWG / MCM	Lagging Power Factor in Percent 100	95	90	85	80	75
1/6-340	6	0.834	0.813	0.780	0.744	0.707	0.670
1/4-402	4	0.525	0.518	0.500	0.480	0.458	0.436
1/3-449	3	0.418	0.416	0.403	0.388	0.372	0.355
1/2-449	2	0.331	0.334	0.325	0.314	0.302	0.289
1/1-496	1	0.263	0.269	0.263	0.255	0.246	0.237
1/1/0-512	1/0	0.210	0.218	0.214	0.209	0.203	0.196
1/2/0-580	2/0	0.167	0.177	0.175	0.172	0.168	0.163
1/3/0-621	3/0	0.135	0.145	0.145	0.144	0.141	0.138
1/4/0-684	4/0	0.109	0.120	0.122	0.121	0.120	0.118
1/250-746	250	0.093	0.105	0.107	0.107	0.107	0.105
1/350-834	350	0.071	0.084	0.087	0.088	0.088	0.087
1/500-1000	500	0.054	0.067	0.071	0.073	0.074	0.074

TABLE 3 - voltage drop Factor A - for three conductor cable - 90°C conductor temperature

Cable Reference	Conductor Size AWG / MCM	Lagging Power Factor in Percent 100	95	90	85	80	75
3/14-387	14	5.587	5.328	5.057	4.783	4.508	4.233
3/12-480	12	3.508	3.352	3.184	3.014	2.843	2.671
3/10-480	10	2.209	2.116	2.012	1.907	1.801	1.694
3/8-590	8	1.389	1.336	1.273	1.208	1.143	1.077
3/6-621	6	0.873	0.845	0.808	0.769	0.729	0.688
3/4-746	4	0.549	0.536	0.515	0.492	0.468	0.443

TABLE 4 - voltage drop Factor A - for three conductor cable - 75°C conductor temperature

Cable Reference	Conductor Size AWG / MCM	Lagging Power Factor in Percent 100	95	90	85	80	75
3/14-387	14	5.329	5.083	4.824	4.564	4.302	4.039
3/12-480	12	3.346	3.198	3.038	2.876	2.713	2.549
3/10-480	10	2.107	2.019	1.921	1.820	1.719	1.617
3/8-590	8	1.324	1.275	1.215	1.154	1.092	1.029
3/6-621	6	0.833	0.807	0.772	0.734	0.696	0.658
3/4-746	4	0.524	0.512	0.492	0.470	0.448	0.424

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Reference List

Websites

International Electrotechnical Commission (IEC), 2012. [online] Available at: <http://www.iec.ch/about/> [Accessed 10 February 2012].

The International Maritime Organization (IMO), 2012. [online] Available at: <http://www.imo.org/Publications/Pages/CatalogueAndBookCodeLists.aspx> [Accessed 10 February 2012].

All About Circuits, 2012. *Three-phase power systems.* [online] Available at: <http://www.allaboutcircuits.com/vol_2/chpt_10/2.html> [Accessed 10 February 2012].

Shanghai Metals Market, 2012. [online] Available at: <http://en.smm.cn/> [Accessed 10 February 2012].

WT Henley, 2006. *SUBSEA Cable Accessories*. [online] Available at: <http://www.wt-henley.com/products/Subsea%20Cable%20accessories.html> [Accessed 10 February 2012].

Thorne and Derrick UK, 2012. *Heat Shrink Cable Joints to suit Multi-Core XLPE, EPR, PVC Cables 600/1000v - 3.3kV.* [online] Available at: <http://www.cablejoints.co.uk/sub-product-details/heat-shrink-cable-joints-cable-terminations/heat-shrink-cable-joints-XLPE-EPR-PVC> [Accessed 10 February 2012].

General Electric Company, 2012. *PQM Power Quality Meter.* [online] Available at: <http://www.gedigitalenergy.com/multilin/catalog/pqm.htm> [Accessed 10 February 2012].

Datawell BV, 2011. *Directional Waveride MK III.*[online] Available at: <http://www.datawell.nl/inhoud.php?id=3> [Accessed 10 February 2012].

Nortek AS, 2012. *AWAC*. [online] Available at: <http://www.nortek.no/en/products/wave-systems/awac> [Accessed 10 February 2012].

Elster, 2012. *A1700D meter brochure* and *A1700INO Elster Meter In-out Modules*. [online] Available at: < http://www.elstermetering.com/en/969.html> [Accessed 10 February 2012].

Schnieder Electric, 2012. *Catalog ION 7650 meter.* [online] Available at: <http://www2.schneider-electric.com/> [Accessed 10 February 2012].

Eaton, 2012. [online] Available at: <http://powerquality.eaton.com/UPS/selector/SolutionEMEA.asp?SOLID=650539&ResellerIDCode=1> [Accessed 10 February 2012].

FG Wilson, 2012. *P26-1S.* [online] Available at: <http://www.fgwilson.com/cda/files/2076241/7/P26-1S%284PP%29GB%280211%29.pdf> [Accessed 10 February 2012].

Alternative Energy Generation, 2012. *Northern Power Systems Northwind 100 - 100kW wind turbine.* [online] Available at: <http://altergen.co.uk/WindTurbine100kW.html> [Accessed 10 February 2012].

Suntech Power Holdings Co., 2012. [online] Available at: <www.suntech-power.com> [Accessed 10 February 2012].

Cablesizer, 2011. *Principles of Cable Sizing.* [online] Available at: <http://www.cablesizer.com/> [Accessed 10 February 2012].

Literature

European Marine Energy Centre Ltd., “Assessment of Performance of Wave Energy Conversion Systems”(2009).

European Marine Energy Centre Ltd., “Assessment of Performance for Tidal Energy Conversion Systems”, (2008).

European Marine Energy Centre Ltd., “Guidance for Developers at EMEC Grid Connected Sites: Supporting Environmental Documentation”, (2011).

European Marine Energy Centre Ltd., “Report on Measurement of Resource and Device Perfomrance for Wave and Tidal Stream Device Testing”, (2012).