Foreword

IDC Technologies specializes in providing high quality state-of-the-art technical training workshops to engineers, scientists and technicians throughout the world. More than 50,000 engineers have attended IDC's workshops over the past 10 years. The tremendous success of the technical training workshops is based in part on the enormous investment IDC puts into constant review and updating of the workshops, an unwavering commitment to the highest quality standards and most importantly - enthusiastic, experienced IDC engineers who present the workshops and keep up-to-date with consultancy work.

Concepts that are important and useful to the engineer, scientist and technician, independent of discipline, are covered in this useful booklet.

Although IDC Technologies was founded in Western Australia in 1986, it now draws engineers from all countries. IDC Technologies currently has offices in Australia, Canada, Ireland, Malaysia, New Zealand, Singapore, South Africa, UK and USA.

We have produced this booklet so that you will get an in-depth, practical coverage of Communications, LANs and TCP/IP topics. Information at an advanced level can be gained from attendance at one of IDC Technologies Practical Training Workshops. Held across the globe, these workshops will sharpen your skills in today's competitive engineering environment.

Other books in this series

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Chapter 1
Power Quality

This chapter is broken down into:

- Basic Definitions
- Recommended Design and Installation Practices
- Zero Signal Reference Grid

Basic Definitions

**Sag**

Momentry: A temporary RMS reduction in the normal AC voltage, at the power frequency, for durations from a half-cycle to two seconds.

Sustained: A RMS reduction in the nominal AC voltage, at the power frequency, for durations greater than two seconds.

![Sag Diagram](image)
Surges and Transients

What we used to call transients, spikes or impulses are now formally known as surges. This is the change that took place in the definitions chapter which is affecting all the IEEE definitions throughout their publications. Figure 1.3 is of a very abrupt subcycle type of disturbance, a very brief and very steep wave front. It shows the line to neutral impulse first taking place on a very short millisecond trace at the bottom of the page and then taking place on a microsecond per division so that the centre of the bottom trace is now expanded to 128 microseconds from left to right on the upper trace. Now we get to see what that actual peak is, something far different from what we see on the bottom where we notice that there is somewhere in the neighbourhood of 600 volts of impulse now known by the term surge.

---

Swell

Momentary: A temporary RMS increase in the normal AC voltage, at the power frequency, for durations from a half-cycle to two seconds.

Sustained: A RMS increase in the nominal AC voltage, at the power frequency for durations greater than two seconds.
Harmonics and Distortions

**Harmonics**
The mathematical representation of the distortion of the pure sine wave. Frequency of these harmonics are obtained by multiplying the harmonic number by the Fundamental Frequency (50/60 Hz).

**Distortion Factor**
The ratio of the root-mean-square of the total harmonic content to the root-mean-square value of the fundamental quantity, expressed as a percentage.

---

Interruptions

**Interruption (Outage)**
- **Momentary:** The complete loss of voltage for a time period between a half cycle and two seconds.
- **Sustained:** The complete loss of voltage for a time period greater than two seconds.

---

Figure 1.5 speaks for itself. Obviously, the momentary loss for something having a half cycle up to two seconds worth of duration and then the definition of having a complete loss would be that power interruption that takes place over a two second long period.
Noise Disturbances

Figure 1.6

Noise

Electrical noise is unwanted electrical signals, which produce undesirable effects in the circuits of the sensitive electronic equipment in which they occur.

Figure 1.6

Notching

Figure 1.7

Notch

A switching (or other) disturbance of the normal power voltage waveform, lasting less than a half-cycle; which is initially of opposite polarity to the waveform, and is thus subtractive from the normal waveform in terms of the peak value of the disturbance voltage. This includes complete loss of voltage for up to a half-cycle. See: Surge.

Noise Definitions

Figure 1.8

Noise, Common Mode

The noise voltage which appears equally and in phase from each signal conductor and ground.

Noise, Transverse Mode

(With reference to a load device input AC power). Noise signals measurable between or among active circuit conductors feeding the subject load, but not between the equipment grounding conductor or associated signal reference structure and the active circuit conductors.
In our electrical noise definitions we have the definition for common mode noise and the definition for transverse mode noise. The common mode noise is more of what we might call the mystery noise circulating in the building where the noise appears between the wires, either the neutral wire or the power phase wire and ground reference.

This noise is not visible between the phase wires themselves or phase to neutral conditions as we will see later on in our explanations. But rather noise that is seeking to find the common conductor, the ground or earthing conductor that we would have in our wiring. By complement, the transverse noise is the other type of noise. Noise that is not so much a mystery. Noise that we will see occurring in the various types of disturbances from line to line or line to neutral as it is wired in the power circuit. The transverse or the normal mode noise we can see with line to line measurements. The common mode noise is always going to have to be examined with respect to the earthing conductor or the earth ground.

Recommended Design and Installation Practices

"Worst" Condition

Figure 1.9 takes a look at four conditions of general wiring. On the left hand side, the picture labelled "The Worst Condition" is where we have taken a single feeder from a power source. We have taken it to a remote location where there are sensitive units as well as noise producing units, such as air conditioning compressors. We have wired it to one single panel board and now we have the noise producing equipment on the same electrical bus with the noise sensitive equipment.

"Fair" - Slightly Better

In Figure 1.9 we have put in two panel boards on that same singular feeder separating the two types of loads by a little bit of wire. It is a fair improvement, but certainly not the only measure that should be taken.

"Better" - Gets the Job Done

In the picture labelled "Better" what we have done is introduced the use of the two-winding transformer to separate the sensitive equipment from a primary bus which has noise producing equipment on it. This transformer has the low internal impedance with the ability to act as a buffer for noise which is coming on the primary side. The buffer does not permit it to pass through the flexible coupling of the primary to the secondary side of the transformer.

"Best" - May not be Available

The picture on the far right is certainly the ultimate in design and application. It involves having multiple feeds, transfer capability and the transformer downstream of it all. It may not be possible due to electrical restrictions in a given area, financial considerations or due to space considerations to engage in the best of practices. But one thing we can concentrate on is the use of the two-winding transformer to help us with the wiring and grounding interfacing that we need between the power source and the load.
Transformer Location

In Figure 1.10, we have the "Poor to Better" comparison of the use of the isolating transformer and some understanding of why it works so well in the way that it is laid out. You will notice in the upper example on this drawing the poor application is where the transformer is located at a considerable distance from the sensitive equipment. In this particular case the equipment is shown as being a computer powered by its own circuit breaker panel in a computer room location. The same application would hold true if it were a computer on a process floor, a computer that was running a telephone system, a network system of personnel computers or any other type of digital logic device. The reason why this application is poor is explained in the paragraph on the figure. The transformer with its grounding point is at a different location from the grounding point of the sensitive equipment in the upper picture.

Zero Signal Reference Grid (ZSRG)
When two or more electronic areas are to be interconnected via metallic signal paths within the same building, the two areas should be separately constructed on their own ZSRG structures and the ZSRG structures should then be interfaced to one another via the use of metallic signal transport ground-plane constructions as shown typically in Figure 1.11.

The signal transport ground-plane is normally constructed of copper foil of about 0.010” thickness or #22 GA galvanized steel strip, and extends at least several inches to either side of the cable(s) laid directly upon it. The foil is often laid into a galvanized steel cable tray and is bonded to it frequently. This form of construction is most suitable where the cables must transit areas within a building which are separated in such a way as to make laying the foil directly upon the floor-slab impractical. This cable tray technique is especially recommended for cables that must be run either vertically or horizontally in such a manner as to place strain on the cables themselves. The tray eliminates this problem.

Cables installed upon a signal transport ground-plane are required to be laid as close to the surface of the ground-plane as is practical, so as to reduce open-loop coupling areas and to allow the electrical fields between the ground-plane and the cables to have maximum coupling via short paths. This practice significantly improves the performance of the resultant installation and provides greater immunity to externally coupled "noise" current electrical fields.

The popular practice of running metallic cables directly between electronics areas in buildings is never a good practice as it always involves problems with common-mode voltages and currents which are always to be expected. Designers should strive to eliminate the practice of directly interconnected equipment wherever possible in these cases. The use of fiber optics is clearly suggested as a better method than using metallic cables between such areas.

In the event that "noise" problems persist in a given cable(s), it is strongly suggested that a Balun transformer be used at each end of the subject cable as a means of increasing the common-mode current path's impedance (more impedance = less current) without affecting the normal-mode signals contained within the cable. In some cases additional cable shielding may be warranted. In some cases a different form of cable driver/receiver design may be indicated. In no case, however, should the grounding system be altered as a means of trying to reduce "noise" problems if the modification either causes violation of the applicable National Electrical Code requirements or of the UL listing (safety) requirements of the subject equipment. Equipment must be either made to operate on the applicable National Electrical Code of Safety Standard acceptable wiring/grounding or it should be replaced with equipment that will operate in such an environment without the creation of safety hazards.

We notice that in data communications cable signal transport between two processing units, these two areas can be interconnected by means of one form or another of a continuous ground plane that we will call the zero signal reference grid (ZSRG). The process described here is to provide as close a coupling between the signal transport system and this common zero reference grid in order to avoid and provide immunity to externally coupled noise and electrical fields. When this is done the open loop coupling areas are made very small and the electrical fields between the ground plane and the cables will have maximum coupling via short paths and thus offer the greatest protection to the signal circuit.
Chapter 2
Electrical Protection for Power Systems

The Need for Electrical Protection

It is not economically feasible to design and manufacture electrical equipment that will never fail in service. Equipment will and does fail, and the only way to limit further damage to equipment, and to restrict danger to human life, is to provide fast, reliable electrical protection. The protection of a power system detects abnormal conditions, localizes faults, and promptly removes the faulty equipment from service.

Protective Relays

A PROTECTIVE RELAY is the device, which operates to disconnect a faulty part of the system, thereby protecting the remainder of the system from further damage. In fact, power protection has the following five main functions as its levels of discipline and functionality, shown in order of priority:

- To ensure safety of personnel
- To safeguard the entire system
- To ensure continuity of supply
- To minimize damage
- To reduce resultant repair costs

All of these requirements make it necessary to ensure early detection, localization, and rapid isolation of electrical faults and additionally prompt and safe removal from service of faulty equipment.

The Basic Requirements of Protection

In order to satisfy the above requirements, protection must therefore have the following qualities:

RELIABILITY:
- To operate in the pre-determined manner when an electrical fault is detected.

SELECTIVITY / DISCRIMINATION:
- To detect and safely isolate only the faulty item(s).

STABILITY / SECURITY:
- To leave all healthy circuits intact and undisturbed and to ensure continuity of supply.

SENSITIVITY:
- To detect even the smallest values of fault current or system abnormalities and operate correctly at its pre-set settings.

SPEED:
- To operate speedily when it is required thereby minimizing damage and ensuring safety to personnel.

Electrical Faults

Electrical faults usually occur due to breakdown of the insulating media between live conductors or between a live conductor and earth. This breakdown may be caused by any one or more of several factors, e.g. mechanical damage, overheating, voltage surges (caused by lightning or switching), ingress of a conducting medium, ionization of air, deterioration of the insulating media due to an unfriendly environment or old age, or misuse of equipment.

Fault currents release an enormous amount of thermal energy, and if not cleared quickly, may cause fire hazards, extensive damage to equipment and risk to human life.

Switchgear needs to be rated to withstand and break the worst possible fault current, which is a solid three-phase short-circuit close to the switchgear. ('Solid' meaning that there is no arc resistance. Normally arc resistance will be present, but this value is unpredictable, as it will depend on where exactly the fault occurs, the actual arcing distance, the properties of the insulating medium at that exact instance, which will be changing all the time due to the heating effect of the arc, etc. Therefore, in fault calculations, the arc resistance is ignored, as it is undeterminable, with the result that the worst case is calculated. The arc resistance will tend to decrease the fault current.)

--- 14 ---

--- 15 ---
Transient & Permanent Faults

Transient faults are faults that do not damage the insulation permanently and as such allow the circuit to be safely re-energized after a short period of time.

A typical example would be an insulator flashover following a lightning strike, which would be successfully cleared on opening of the circuit breaker, which could then be automatically reclosed.

Transient faults occur mainly on outdoor equipment where air is the main insulating medium.

Permanent faults, as the name implies, are the result of permanent damage to the insulation of either the transmission medium or the associated equipment attached to it.

Calculation of Short Circuit Currents

Accurate fault current calculations are normally carried out using an analysis method called "Symmetrical Components." This method involves the use of higher mathematics and is based on the principal that any unbalanced set of vectors can be represented by a set of 3 balanced systems, namely: positive, negative and zero sequence vectors.

However, for general practical purposes it is possible to achieve a good approximation of 3 phase short circuit currents using some very simple methods, which are discussed below.

The short circuit current at the secondary side and close to the transformer, can be quickly calculated by using the following formula:

\[
\text{short-circuit MVA} = \frac{1000 P}{X\%} \\
\text{and Short - circuit current} \quad I_{KA} = \frac{\text{MVA}}{\sqrt{3}} \times kV
\]

where

- \(P\) = Transformer rating in MVA
- \(X\%\) = Internal Reactance of Transformer in %
- \(I_{KA}\) = Short-circuit current in kA
- \(kV\) = Transformer secondary voltage in kV

TYPICAL % reactance values for transformers (X%) are shown in the table below.

<table>
<thead>
<tr>
<th>MVA Rating</th>
<th>Up to 13.8kV</th>
<th>25kV</th>
<th>38kV</th>
<th>69kV</th>
<th>138kV</th>
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<tbody>
<tr>
<td>0.25</td>
<td>3.5</td>
<td>4.0</td>
<td>4.5</td>
<td>5.0</td>
<td>6.5</td>
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<td>4.0</td>
<td>4.5</td>
<td>5.5</td>
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</tr>
<tr>
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<td>5.0</td>
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<td>5.5</td>
<td>6.0</td>
<td>7.0</td>
</tr>
<tr>
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<td>6.5</td>
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</tr>
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<td>6.5</td>
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</tr>
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</tr>
<tr>
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<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Table 2.1

Reactive Values

Normally, the % reactance value of the transformer can be obtained from the nameplate, or if not, from the transformer data sheets.

If a length of cable (more than 100m) exist between the transformer and the fault, the impedance of the cable has to be taken into account to arrive at a realistic value for the worst-case fault current. This is done by calculating the source impedance and then adding the cable impedance, as follows:

\[
Z = \frac{kV}{\sqrt{3}} \times kA
\]

\[
\text{Fault Current kA} = \frac{kV}{(Z_{source} + Z_{cable})}
\]

\(Z_{cable}\) can be obtained from the manufacturer's cable data sheets.

The above calculation is another approximation, as \(Z_{source}\) and \(Z_{cable}\) are not necessarily in phase, and complex algebra should be used. However, it is accurate enough for most practical applications.

Fuses

Probably the oldest, simplest, cheapest and most-often used type of protection device is the fuse. The operation of a fuse is very straightforward: The thermal energy of the excessive current causes the fuse-element to melt and the current...
charge by a battery charger, which normally is rated to have enough capacity to supply the standing load of the switchgear panel (relay auxiliary power, indication lamps, etc.). When a temporary high current is needed, usually to provide a circuit-breaker tripping supply, the batteries will supply this, and be recharged after the event. The batteries then also function as a full back up in case of total power failure.

The AC input to the BTU is usually supplied from the panel VT, or from a lighting transformer.

What often occurs in practice, and which is very bad engineering practice, is to power the relay and trip circuit directly from the panel VT. This will function correctly in most instances, but when a really severe three-phase short-circuit occurs, the voltage of the substation may drop quite dramatically, causing malfunction of the tripping circuit.

There are other ways to overcome this, like capacitive tripping circuits, and AC series tripping schemes, but each has its own disadvantages, and none are as reliable as the DC shunt tripping arrangement.

The circuit breaker opens its main contacts when the tripping signal has been received, interrupting the current.

From the protection point of view the important parts of the circuit breaker are the trip coil, latching mechanism, main contacts and auxiliary contacts.

Circuit breakers are normally fitted with a number of auxiliary contacts, which are used, as needed, in a variety of ways in control and protection circuits. Initially, circuit breakers used air as the insulating medium, later insulating oil (the oil also acting as a cooling medium), and nowadays vacuum or SF6 (sulphur-hexafluoride) gas.

The connection between the relay and the circuit-breaker trip coil is purely electrical. This used to be one possible weak link in the trip circuit. One popular method to increase the reliability of the trip circuit for critical substations is to provide a full back-up trip supply. A back-up trip coil is installed in the circuit breaker, with back-up protection, powered by a second, independent BTU.
Circuit Breaker Tripping Times

The first characteristic is referred to as the "TRIPPING TIME" and is expressed in cycles.

Modern high-speed circuit breakers have tripping times between 3 and 8 cycles.

The TRIPPING, TOTAL BREAK TIME is made up as follows:

1. (Tripping Time) Opening Time:
   This represents the time between the instant of application of tripping power to the instant of mechanical separation of the main contacts.

2. (Tripping Time) Arcing Time:
   The time between the instant of mechanical separation of the main circuit breaker contacts to the instant of arc extinction

The sum of the above: Opening Time + Arcing Time = Breaking Time

Instrument Transformers

The three main tasks of instrument transformers are

1. To transform currents or voltages from a usually high value to a value easy to handle for relays and instruments.
2. To insulate the relays, metering and instruments from the primary high voltage system.
3. To provide possibilities of standardizing the relays and instruments etc. to a few rated currents and voltages.

Current Transformer (CT) Magnetization Curve

This curve is the best method of determining Current Transformer (CT) performance. It is a graph of the amount of magnetizing current required to generate an open-circuit voltage at the terminals of the unit. Due to the non-linearity of the core iron, it follows the B-H loop characteristic and comprises three regions, namely the initial region, unsaturated region and saturated region.
Protection CTs

Protective gear, on the other hand, is concerned with a wide range of currents from fault settings to maximum fault currents many times normal rating. Larger errors may be permitted and it is important to ensure that saturation is avoided wherever possible to ensure positive operation of the relays.

Open Circuiting of CTs

Current transformers generally work at a low flux density. The core is usually made of very good metal to give a small magnetizing current. When it is open circuit the secondary impedance now becomes infinite and the core deeply saturates.

- Flashover will then occur.

NEVER OPEN-CIRCUIT A C.T. ON LOAD!

As all of the primary current now becomes magnetizing current.

As the ac wave then moves from positive half cycle to the negative half cycle, the rate of change of flux \( \frac{d\phi}{dt} \) is so great that very high voltages are induced in the secondary winding.

CT Specification

A current transformer is normally specified in terms of

- A rated burden at rated current.
- An accuracy class.
- An upper limit beyond which accuracy is not guaranteed.

(Known as the Accuracy Limit Factor, ALF).

Special (Class X) Current Transformers

These are normally specified for special purpose applications such as differential protection, where it is important that CTs have matching characteristics.
For this type of CT an exact point on the Magnetization Curve is specified, e.g.
- Rated primary current
- Turns ratio
- Rated knee point e.m.f. at maximum secondary turns
- Maximum exciting current at rated knee point e.m.f.
- Maximum resistance of secondary winding.

In addition, the error in the turns ratio shall not exceed +/- 0.25%.

**Voltage Transformers**

There are two types of voltage transformer used for protection equipment, the purely electro-magnetic type (commonly referred to as a VT) and the Capacitor type (referred to as a CVT).

**Magnetic Voltage Transformer**

The magnetic voltage transformer is similar to a power transformer and differs only in so far as a different emphasis is placed on cooling, insulating and mechanical aspects.

The primary winding has a large number of turns and is connected across the line voltage either line-to-line or line-to-neutral.

The secondary has fewer turns, consequently as the volts per turn remains constant, then less voltage and higher currents are obtained.

Output burdens of 500 VA per phase are common.

**Capacitive Transformer**

The capacitor VT is more commonly used on high voltage networks. The capacitor allows the injection of a high frequency signal onto the power line conductors to provide end-to-end communications between substations for distance relays telemetry/supervisory and voice communications.

---

**IDMT Relays**

It can be seen that the operating time of an IDMT relay is inversely proportional to a function of current, i.e. it has a long operating time at low multiples of setting current and a relatively short operating time at high multiples of setting current.

**Two adjustments are possible on the relay, namely:**

**Current (Tap) Setting**

This setting determines the level of current at which the relay will pick-up or start. Increasing this value will move the IDMT curve to the right of the graph.
**Time Dial Setting**

This setting speeds up the tripping time of the relay, and has the effect of moving the inverse curve down the axis as follows:

![Graph showing Time Dial Setting](image)

*Figure 2.4*  
*Time/Current Characteristic.*

Other characteristic curves are also available, namely VERY INVERSE and EXTREMELY INVERSE. The time curves are shown as follows:

![Graph showing Different Inverse Curves](image)

*Figure 2.5*  
*Example of Different Inverse Curves*
Why IDMT?

To achieve selectivity and co-ordination by time grading two philosophies are available, namely:

- Definite Time Lag (DTL), or
- Inverse Definite Minimum Time (IDMT)

For the first option, the relays are graded using a definite time interval of approximately 0.5 seconds. The relay A at the extremity of the network is set to operate in the fastest possible time, whilst its upstream relay B is set 0.5 seconds higher. Relay operating times increase sequentially at 0.5-second intervals on each section moving back towards the source as shown in Figure 2.6.

The problem with this philosophy is the closer the fault to the source, the higher the fault current, the slower the clearing time - exactly the opposite to what we should be trying to achieve!

On the other hand, inverse curves as shown in Figure 2.7 operate faster at higher fault currents and slower at the lower fault currents, thereby offering us the features that we desire.

This explains why the IDMT philosophy has become standard practice throughout many countries over the years.
Chapter 3
Substation Automation

Definition of the Term

Substation Automation can be defined as a system for managing, controlling and protecting a power system. This is accomplished by obtaining real-time information from the system, having powerful local and remote control applications and advanced electrical protection. The core ingredients of a Substation Automation system are local intelligence, data communications and supervisory control and monitoring.

The term Substation Automation is actually too restrictive and may be misleading. It is too restrictive in the sense that it refers specifically to a substation only. However, the concepts encompassed in the definition have a much wider application than being limited only to substations. It is applicable to electrical power networks at large, from High Voltage transmission networks, to Medium Voltage distribution networks, to Low Voltage reticulation networks.

The term may be misleading in that automation usually refers to some type of process automation, whereas the concepts involved in Substation Automation are quite unique and far removed from process automation, although there is some common ground in the underlying principles.

The term Substation Automation evolved due to the fact that most of the equipment that forms the core of such a system, is located in an electrical substation or switchroom, and these modern, intelligent devices ensure that the need for human presence or intervention in a substation is limited. The components of a Substation Automation system aim to protect, monitor and control a typical electrical substation.

Therefore the term Substation Automation is probably as descriptive as any other, and due to the fact that it already became virtually an international accepted term for the multitude of concepts involved, it is the term that will be used throughout the text.

What is Substation Automation?

Substation Automation may be best described by referring to Figure 3.1.

Substation Automation, by definition, consists of the following main components:

- Electrical Protection
- Control
- Measurement
- Monitoring
- Data Communications
Electrical Protection

Electrical Protection is still one of the most important components of any electrical switchgear panel, in order to protect the equipment and personnel, and to limit damage in case of an electrical fault.

Electrical protection is a local function, and should be able to function independently of the Substation Automation system if necessary, although it is an integral part of Substation Automation under normal conditions. The functions of electrical protection should never be compromised or restricted in any Substation Automation system.

Control

Control includes local and remote control. Local control consists of actions the control device can logically take by itself, for example bay interlocking, switching sequences and synchronising check. Human intervention is limited and the risk of human error is greatly reduced.

Local control should also continue to function even without the support of the rest of the Substation Automation system.

Commands can be given directly to the remote controlled devices, for example open or close a circuit breaker. Relay settings can be changed via the system, and requests for certain information can be initiated from the SCADA station(s). This eliminates the need for personnel to go to the substation to perform switching operations, and switching actions can be performed much faster, which is a tremendous advantage in emergency situations.

A safer working environment is created for personnel, and huge production losses may be prevented. In addition, the operator or engineer at the SCADA terminal has a holistic overview of what is happening in the power network throughout the plant or factory, improving the quality of decision-making.

Measurement

A wealth of real-time information about a substation or switchgear panel is collected, which are typically displayed in a central control room and/or stored in a central database. Measurement consists of:

- Electrical measurements (including metering) - voltages, currents, power, power factor, harmonics, etc.
- Other analog measurements, eg. transformer and motor temperatures
- Disturbance recordings for fault analyzes

This makes it unnecessary for personnel to go to a substation to collect information, again creating a safer work environment and cutting down on personnel workloads.

The huge amount of real-time information collected can assist tremendously in doing network studies like load flow analyzes, planning ahead and preventing major disturbances in the power network, causing huge production losses.

Note:

The term 'measurement' is normally used in the electrical environment to refer to voltage, current and frequency, while 'metering' is used to refer to power, reactive power, and energy (kWh). The different terms originated due to the fact that very different instruments were historically used for measurement and metering. Nowadays the two functions are integrated in modern devices, with no real distinction between them, hence the terms 'measurement' and 'metering' are used interchangeably in the text. Accurate metering for billing purposes is still performed by dedicated instruments.

Monitoring

- Sequence-of-Event Recordings
- Status and condition monitoring, including maintenance information, relay settings, etc.

This information can assist in fault analyzes, determining what happened, where and in what sequence. This can be used effectively to improve the efficiency of the power system and the protection. Preventative maintenance procedures can be utilized by the condition monitoring information obtained.
The modern system consists of three main divisions:

**Object Division**

The object division of the Substation Automation system consists of Intelligent Electronic Devices (IEDs), modern, 3rd generation microprocessor based relays and/or Remote Terminal Units (RTUs). (PLCs also continue to play an important role in some systems.) They receive analog inputs from the Current Transformers (CTs), Voltage Transformers (VTs) and transducers in the various switchgear panels, as well as digital inputs from auxiliary contacts, other field devices or IEDs, or the SCADA Master. They are able to perform complex logical and mathematical calculations and provide an output either to the SCADA Master, other field instruments or IEDs, or back to the switchgear to perform some command, for example open a circuit breaker.

The component division consists of the process level (field information from CTs, VTs, etc) and the bay level (local intelligence in the form of IEDs, RTUs, etc).

**The Communications Network**

The Communications Network (comms network for short) is virtually the nervous system of Substation Automation. The comms network ensures that raw data, processed information and commands are relayed quickly, effectively and error-free among the various field instruments, IEDs and the SCADA system. The physical medium will generally be fiber-optic cables in modern networks, although some copper wiring will still exist between the various devices inside a substation.

The comms network needs to be an ‘intelligent’ subsystem in its own right to perform the functions required of it, and is not merely a network of fiber-optic and copper wiring.

The communication network serves as the interface between the bay level and the SCADA station level, which might be a SCADA master station in the substation itself, or remotely in a central control room.

**SCADA Master**

The SCADA (Supervisory Control And Data Acquisition) master station(s) forms the virtual brain of the Substation Automation system. The SCADA master
receives data and information from the field, decides what to do with it, stores it (directly or after some form of processing), and issues requests and/or commands to the remote devices. Therefore, the SCADA master is effectively in control of the complete Substation Automation system.

Nowadays, a SCADA master consists simply of an advanced, reliable PC or workstation (with its peripheral and support hardware) and a SCADA software package.

A SCADA master station may be installed in each substation of a power transmission network (station level), with all the substation SCADA stations forming part of a LAN or WAN (network level); or one SCADA master station may be directly in control of several substations, eliminating the station level.

**Communication Protocols used in Substation Automation**

Some of the more popular and widely used communication protocols are listed in table 3.1, with specific reference to protocols used in Substations at present.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Originally Used by</th>
<th>Speed</th>
<th>Access Principle</th>
<th>OSI Layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODBUS</td>
<td>Gould-Modicon</td>
<td>19.2 kb/s</td>
<td>Cyclic Polling</td>
<td>1,2,7</td>
</tr>
<tr>
<td>SPABUS</td>
<td>ABB (exclusively)</td>
<td>19.2 kb/s</td>
<td>Cyclic Polling</td>
<td>1,2,7</td>
</tr>
<tr>
<td>DNP3.0</td>
<td>GE Harris</td>
<td>19.2 kb/s</td>
<td>Cyclic Polling (+)</td>
<td>1,2,7 (+)</td>
</tr>
<tr>
<td>IEC 60870-5</td>
<td>All</td>
<td>19.2 kb/s</td>
<td>Cyclic Polling</td>
<td>1,2,7</td>
</tr>
<tr>
<td>MODBUS +</td>
<td>Gould-Modicon</td>
<td>1.2 Mb/s</td>
<td>Token</td>
<td>1,2,7</td>
</tr>
<tr>
<td>PROFIBUS</td>
<td>Siemens</td>
<td>0.5 Mb/s</td>
<td>Token</td>
<td>1,2,7</td>
</tr>
<tr>
<td>MVB</td>
<td>ABB</td>
<td>1.5 Mb/s</td>
<td>TDM</td>
<td>1,2,7 (+)</td>
</tr>
<tr>
<td>PNP</td>
<td>Merlin-Gerin</td>
<td>2.5 Mb/s</td>
<td>TDM</td>
<td>1,2,7</td>
</tr>
<tr>
<td>Ethernet + TCP/IP</td>
<td>All</td>
<td>10 Mb/s</td>
<td>CSMA/CD</td>
<td>1-7</td>
</tr>
<tr>
<td>LON</td>
<td>ABB (exclusively)</td>
<td>1.25 Mb/s</td>
<td>PCSMA/CD</td>
<td>1-7</td>
</tr>
<tr>
<td>UCA 2.0</td>
<td>GE</td>
<td>10 Mb/s</td>
<td>CSMA/CD</td>
<td>1-7</td>
</tr>
</tbody>
</table>

Table 3.1

*Protocols used in Substations*

The Process level consists of:

- The equipment providing information to the bay level, e.g. instrument transformers, temperature sensors, auxiliary contacts of circuit breakers, etc. The application process is therefore a voltage, current, temperature, breaker status, etc.

- The equipment executing a command from the bay level, e.g. trip coil of circuit breaker. The application process is then the command 'open breaker'.

The Bay level consists of four main application processes (APs): Protection, Control, Measurement/Metering, and Monitoring. These APs can reside in different devices, or all in one device (the typical IED).
The Station level consists of the Station SCADA (optional) and possibly a gateway or communications processor. The importance of the Station SCADA will depend on the specific application. In large transmission substations, this will form the main SCADA for the specific substation, with several SCADA systems forming a network. On the other hand, for a distribution substation, the Station SCADA may be dispensed with, and only a gateway will be required to connect the substation to the network and to the main SCADA.

The network level may consist of a central SCADA, to which each substation is connected, and/or a LAN, MAN, WAN or the Internet.

Communication Requirements

The communication requirements for the various applications in substation automation will be evaluated in this section according to the following attributes:

![Table 3.2 Communication Requirements](image)

Appendix A
Glossary of Terms

10BASE2 IEEE802.3 (or Ethernet) implementation on thin coaxial cable (RG58/AU).

10BASE5 IEEE802.3 (or Ethernet) implementation on thick coaxial cable.

10BASET IEEE802.3 (or Ethernet) implementation on unshielded 22 AWG twisted pair cable.

A/D Conversion Time This is the length of time a board requires to convert an analog signal into a digital value. The theoretical maximum speed (conversions/second) is the inverse of this value. See Speed/Typical Throughput.

A/D Analog to Digital conversion.

Absolute Addressing A mode of addressing containing both the instruction and location (address) of data.

Accuracy Closeness of indicated or displayed value to the ideal measured value.

ACK Acknowledge (ASCII - control F). Acknowledge A handshake line or protocol code which is used by the receiving device to indicate that it has read the transmitted data.

Active Device Device capable of supplying current for a loop.

Active Filter A combination of active circuit devices (usually amplifiers), with passive circuit elements (resistors and capacitors), which have characteristics that more closely match ideal filters than do passive filters.

AFC Automatic Frequency Control. The circuit in a radio receiver that automatically keeps the carrier frequency centred in the passband of the filters and demodulators.

AGC Automatic Gain Control. The circuit in a radio that automatically keeps the carrier gain at the proper level.
Algorithm
Can be used as a basis for writing a computer program. This is a set of rules with a finite number of steps for solving a problem.

Alien-Frequency
A false lower frequency component that appears in data reconstructed from original data acquired at an insufficient sampling rate (less than two times the maximum frequency of the original data).

ALU
see Arithmetic Logic Unit.

Amplitude Modulation
A modulation technique (also referred to as AM or ASK) used to allow data to be transmitted across an analog network, such as a switched telephone network. The amplitude of a single (carrier) frequency is varied or modulated between two levels, one for binary 0 and one for binary 1.

Analog
A continuous real-time phenomenon in which the information values are represented in a variable and continuous waveform.

Analog Input Board
Printed Circuit Board which converts incoming analog signals to digital values.

ANSI
American National Standards Institute. The principle standards development body in the USA.

Apogee
The point in an elliptical orbit that is furthest from earth.

Appletalk
A proprietary computer networking standard initiated by Apple Computer for use in connecting the Macintosh range of computers and peripherals (including Laser Writer printers). This standard operates at 230 kilobits/second.

Application Program
A sequence of instructions written to solve a specific problem facing organisational management. These programs are normally written in a high-level language and draw on resources of the operating system and the computer hardware in executing its tasks.

Application Layer
The highest layer of the seven layer ISO/OSI Reference Model structure, which contains all user or application programs.

Arithmetic Logic Unit
The element(s) in a processing system that performs the mathematical functions such as addition, subtraction, multiplication, division, inversion, AND, OR, NAND and NOR.

ARP
Address Resolution Protocol. A Transmission Control Protocol/Internet Protocol (TCP/IP) process that maps an IP address to Ethernet address, required by TCP/IP for use with Ethernet.

ARQ
Automatic Request for Transmission. A request by the receiver for the transmitter to retransmit a block or a frame because of errors detected in the originally received message.

Australian Standard.
Bipolar Range / Inputs
A signal range that includes both positive and negative values. Bipolar inputs are designed to accept both positive and negative voltages. (Example: ±5 V).

Bisynchronous Transmission
See BSC.

Bit Stuffing with Zero Bit Insertion
A technique used to allow pure binary data to be transmitted on a synchronous transmission line. Each message block (frame) is encapsulated between two flags which are special bit sequences. Then if the message data contains a possibly similar sequence, an additional (zero) bit is inserted into the data stream by the sender, and is subsequently removed by the receiving device. The transmission method is then said to be data transparent.

BIT (Binary Digit)
Derived from "Binary Digit", a one or zero condition in the binary system.

Bits & Bytes
One bit is one binary digit, either a binary 0 or 1. One byte is the amount of memory needed to store each character of information (text or numbers). There are eight bits to one byte (or character), and there are 1024 bytes to one kilobyte (KB). There are 1024 kilobytes to one megabyte (MB).

Block
In block-structured programming languages, a section of program coding treated as a unit.

Block Sum Check
This is used for the detection of errors when data is being transmitted. It comprises a set of binary digits (bits) which are the modulo 2 sum of the individual characters or octets in a frame (block) or message.

BNC
Bayonet type coaxial cable connector.

bps
Bits per second. Unit of data transmission rate.

Bridge
A device to connect similar sub-networks without its own network address. Used mostly to reduce the network load.

Broad Band
A communications channel that has greater bandwidth than a voice grade line and is potentially capable of greater transmission rates.

Broadcast
A message on a bus intended for all devices which requires no reply.

BS
Backspace (ASCII Control-H).

British Standard.

BSC
Bisynchronous Transmission. A byte or character oriented communication protocol that has become the industry standard (created by IBM). It uses a defined set of control characters for synchronised transmission of binary coded data between stations in a data communications system.
Characteristic Impedance: The impedance that, when connected to the output terminals of a transmission line of any length, makes the line appear infinitely long. The ratio of voltage to current at every point along a transmission line on which there are no standing waves.

Clock: The source of timing signals for sequencing electronic events such as synchronous data transfer or CPU operation in a PC.

Clock Pulse: A rising edge, then a falling edge (in that order) such as applied to the clock input of an 8254 timer/counter.

Clock: The source(s) of timing signals for sequencing electronic events e.g. synchronous data transfer.

Closed Loop: A signal path that has a forward route for the signal, a feedback network for the signal and a summing point.

CMRR: Common Mode Rejection Ratio - A data acquisition's board's ability to measure only the voltage difference between the leads of a transducer, rejecting what the leads have in common. The higher the CMRR, the better the accuracy.

CMV: Common Mode Voltage.

CNR: Carrier to Noise Ratio. An indication of the quality of the modulated signal.

Cold-junction Compensation: Thermocouple measurements can easily be affected by the interface the thermocouples are connected to. Cold-junction compensation circuitry compensates for inaccuracies introduced in the conversion process.

Collector: The voltage source in a transistor with the base as the control source and the emitter as the controlled output.

Collision: The situation when two or more LAN nodes attempt to transmit at the same time.

Common Carrier: A private data communications utility company that furnishes communications services to the general public.

Common Mode Signal: The common voltage to the two parts of a differential signal applied to a balanced circuit.

Commutator: A device used to effect time-division multiplexing by repetitive sequential switching.

Compiler: A program to convert high-level source code (such as BASIC) to machine code-executable form, suitable for the CPU.

Composite Link: The line or circuit connecting a pair of multiplexers or concentrators; the circuit carrying multiplexed data.

Composite: A video signal that contains all the intensity, color and timing information necessary for a video product.
Current Sink
This is the amount of current the board can supply for digital output signals. With 10-12 mA or more of current sink capability, a board can turn relays on and off. Digital I/O boards with less than 10-12 mA of sink capability are designed for data transfer only, not for hardware power relay switching.

Current Loop
A communication method that allows data to be transmitted over a longer distance with a higher noise immunity level than with the standard RS-232C voltage method.

Current Inputs
A board rated for current inputs can accept and convert analog current levels directly, without conversion to voltage.

D/A
Digital to Analog.

DAS
Data Acquisition System.

Data Integrity
A performance measure based on the rate of undetected errors.

Data Reduction
The process of analyzing a large quantity of data in order to extract some statistical summary of the underlying parameters.

Data Link Layer
This corresponds to layer 2 of the ISO Reference Model for open systems interconnection. It is concerned with the reliable transfer of data (no residual transmission errors) across the data link being used.

Data Integrity
A performance measure based on the rate of undetected errors.

Datagram
A type of service offered on a packet-switched data network. A datagram is a self-contained packet of information that is sent through the network with minimum protocol overheads.

dBi
A unit that is used to represent the gain of an antenna compared to the gain of an isotropic radiator.

dBm
A signal level that is compared to a 1-mW reference.

dBmV
A signal amplitude that is compared to a 1-mV reference.

dBW
A signal amplitude that is compared to a 1-Watt reference.

DCE
Data Communications Equipment. Devices that provide the functions required to establish, maintain and terminate a data transmission connection. Normally it refers to a modem.

Decibel
A logarithmic measure of the ratio of two signal levels where dB = 20log10(V1/V2). Being a ratio, it has no units of measure.

Decibel (dB)
A logarithmic measure of the ratio of two signal levels where dB = 20log10(P1/P2) or where dB = 10log10(V1/V2) and where V refers to Voltage or P refers to Power. Note that it has no unit of measure.
<table>
<thead>
<tr>
<th><strong>Decoder</strong></th>
<th>A device that converts a combination of signals into a single signal representing that combination.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Decommutator</strong></td>
<td>Equipment for the demultiplexing of commutated signals.</td>
</tr>
<tr>
<td><strong>Default</strong></td>
<td>A value or setup condition assigned automatically unless another is specified.</td>
</tr>
<tr>
<td><strong>Delay Distortion</strong></td>
<td>Distortion of a signal caused by the frequency components making up the signal having different propagation velocities across a transmission medium.</td>
</tr>
<tr>
<td><strong>DES</strong></td>
<td>Data Encryption Standard.</td>
</tr>
<tr>
<td><strong>Deviation</strong></td>
<td>A movement away from a required value.</td>
</tr>
<tr>
<td><strong>DFB</strong></td>
<td>Display Frame Buffer.</td>
</tr>
<tr>
<td><strong>Diagnostic Program</strong></td>
<td>A utility program used to identify hardware and firmware defects related to the PC.</td>
</tr>
<tr>
<td><strong>Dielectric Constant (E)</strong></td>
<td>The ratio of the capacitance using the material in question as the dielectric, to the capacitance resulting when the material is replaced by air.</td>
</tr>
<tr>
<td><strong>Differential</strong></td>
<td>See Number of channels.</td>
</tr>
<tr>
<td><strong>Digital</strong></td>
<td>A signal which has definite states (normally two).</td>
</tr>
<tr>
<td><strong>Digitise</strong></td>
<td>The transformation of an analog signal to a digital signal.</td>
</tr>
<tr>
<td><strong>DIN</strong></td>
<td>Deutsches Institut Fur Normierung.</td>
</tr>
<tr>
<td><strong>DIP</strong></td>
<td>Acronym for dual in line package referring to integrated circuits and switches.</td>
</tr>
<tr>
<td><strong>Duplexing</strong></td>
<td>A device used to allow simultaneous reception or transmission of two signals on a common antenna.</td>
</tr>
<tr>
<td><strong>Direct Memory Access</strong></td>
<td>A technique of transferring data between the computer memory and a device on the computer bus without the intervention of the microprocessor. Also abbreviated to DMA.</td>
</tr>
<tr>
<td><strong>Discriminator</strong></td>
<td>Hardware device to demodulate a frequency modulated carrier or subcarrier to produce analog data.</td>
</tr>
<tr>
<td><strong>Dish Antenna</strong></td>
<td>An antenna in which a parabolic dish acts a reflector to increase the gain of the antenna.</td>
</tr>
<tr>
<td><strong>Dish</strong></td>
<td>Concave antenna reflector for use at VHF or higher frequencies.</td>
</tr>
<tr>
<td><strong>Diversity Reception</strong></td>
<td>Two or more radio receivers connected to different antennas to improve signal quality by using two different radio signals to transfer the information.</td>
</tr>
<tr>
<td><strong>DLE</strong></td>
<td>Data Link Escape (ASCII character).</td>
</tr>
<tr>
<td><strong>DMA</strong></td>
<td>Direct Memory Access.</td>
</tr>
<tr>
<td><strong>DNA</strong></td>
<td>Distributed Network Architecture.</td>
</tr>
<tr>
<td><strong>Doppler</strong></td>
<td>The change in observed frequency of a signal caused by the emitting device moving with respect to the observing device.</td>
</tr>
<tr>
<td><strong>Downlink</strong></td>
<td>The path from a satellite to an earth station.</td>
</tr>
<tr>
<td><strong>DPI</strong></td>
<td>Dots per Inch.</td>
</tr>
<tr>
<td><strong>DPLL</strong></td>
<td>Digital Phase Locked Loop.</td>
</tr>
<tr>
<td><strong>DR</strong></td>
<td>Dynamic Range. The ratio of the full scale range (FSR) of a data converter to the smallest difference it can resolve. ( DR = 2^n ) where ( n ) is the resolution in bits.</td>
</tr>
<tr>
<td><strong>DRAM</strong></td>
<td>Dynamic Random Access Memory. See RAM.</td>
</tr>
<tr>
<td><strong>Drift</strong></td>
<td>A gradual movement away from the defined input/output condition over a period of time.</td>
</tr>
<tr>
<td><strong>Driver Software</strong></td>
<td>A program that acts as the interface between a higher level coding structure and the lower level hardware/firmware component of a computer.</td>
</tr>
<tr>
<td><strong>DSP</strong></td>
<td>Digital Signal Processing.</td>
</tr>
<tr>
<td><strong>DSR</strong></td>
<td>Data Set Ready. An RS-232 modem interface control signal which indicates that the terminal is ready for transmission.</td>
</tr>
<tr>
<td><strong>DTE</strong></td>
<td>Data Terminal Equipment. Devices acting as data source, data sink, or both.</td>
</tr>
<tr>
<td><strong>Dual-ported RAM</strong></td>
<td>Allows acquired data to be transferred from on-board memory to the computer's memory while data acquisition is occurring.</td>
</tr>
<tr>
<td><strong>Duplex</strong></td>
<td>The ability to send and receive data over the same communications line.</td>
</tr>
<tr>
<td><strong>Dynamic Range</strong></td>
<td>The difference in decibels between the overload or maximum and minimum discernible signal level in a system.</td>
</tr>
<tr>
<td><strong>EBTDC</strong></td>
<td>Extended Binary Coded Decimal Interchange Code. An 8-bit character code used primarily in IBM equipment. The code allows for 256 different bit patterns.</td>
</tr>
<tr>
<td><strong>EEPROM</strong></td>
<td>Electrically Erasable Programmable Read Only Memory. This memory unit can be erased by applying an electrical signal to the EEPROM and then reprogrammed.</td>
</tr>
<tr>
<td><strong>EGA</strong></td>
<td>Enhanced Graphics Adapter. A computer display standard that provides a resolution of 640 by 350 pixels, a palette of 64 colors, and the ability to display as many as 16 colors at one time.</td>
</tr>
<tr>
<td><strong>EIA</strong></td>
<td>Electronic Industries Association. An organisation in the USA specializing in the electrical and functional characteristics of interface equipment.</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>EIA-232-C</td>
<td>Interface between DTE and DCE, employing serial binary data exchange. Typical maximum specifications are 15m at 19200 Baud.</td>
</tr>
<tr>
<td>EIA-423</td>
<td>Interface between DTE and DCE, employing the electrical characteristics of unbalanced voltage digital interface circuits.</td>
</tr>
<tr>
<td>EIA-449</td>
<td>General purpose 37 pin and 9 pin interface for DCE and DTE employing serial binary interchange.</td>
</tr>
<tr>
<td>EIA-485</td>
<td>The recommended standard of the EIA that specifies the electrical characteristics of drivers and receivers for use in balanced digital multipoint systems.</td>
</tr>
<tr>
<td>EIRP</td>
<td>Effective Isotropic Radiated Power. The effective power radiated from a transmitting antenna when an isotropic radiator is used to determine the gain of the antenna.</td>
</tr>
<tr>
<td>EM/RFI</td>
<td>Electromagnetic Interference or Radio Frequency Interference. Background 'noise' capable of modifying or destroying data transmission.</td>
</tr>
<tr>
<td>EMS</td>
<td>Expanded Memory Specification.</td>
</tr>
<tr>
<td>Emulation</td>
<td>The imitation of a computer system performed by a combination of hardware and software that allows programs to run between incompatible systems.</td>
</tr>
<tr>
<td>Enabling</td>
<td>The activation of a function of a device by a defined signal.</td>
</tr>
<tr>
<td>Encoder</td>
<td>A circuit which changes a given signal into a coded combination for purposes of optimum transmission of the signal.</td>
</tr>
<tr>
<td>ENQ</td>
<td>Enquiry (ASCII Control-E).</td>
</tr>
<tr>
<td>EOT</td>
<td>End of Transmission (ASCII Control-D).</td>
</tr>
<tr>
<td>EPROM</td>
<td>Erasable Programmable Read Only Memory. Non-volatile semiconductor memory that is erasable in a ultra violet light and reprogrammable.</td>
</tr>
<tr>
<td>Equaliser</td>
<td>The device which compensates for the unequal gain characteristic of the signal received.</td>
</tr>
<tr>
<td>Error Rate</td>
<td>The ratio of the average number of bits that will be corrupted to the total number of bits that are transmitted for a data link or system.</td>
</tr>
<tr>
<td>Error</td>
<td>The difference between the setpoint and the measured value.</td>
</tr>
<tr>
<td>ESC</td>
<td>Escape (ASCII character).</td>
</tr>
<tr>
<td>ESD</td>
<td>Electrostatic Discharge.</td>
</tr>
<tr>
<td>Ethernet</td>
<td>Name of a widely used Local Area Network (LAN), based on the CSMA/CD bus access method (IEEE 802.3).</td>
</tr>
<tr>
<td>ETX</td>
<td>End of Text (ASCII control-C).</td>
</tr>
</tbody>
</table>

### Power Systems Protection, Power Quality, Substation Automation

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Even Parity</td>
<td>A data verification method normally implemented in hardware in which each character (and the parity bit) must have an even number of ON bits.</td>
</tr>
<tr>
<td>External Pulse Trigger</td>
<td>Many of the A/D boards allow sampling to be triggered by a voltage pulse from an external source.</td>
</tr>
<tr>
<td>Fan In</td>
<td>The load placed on a signal line by a logic circuit input.</td>
</tr>
<tr>
<td>Fan Out</td>
<td>The measure of drive capability of a logic circuit output.</td>
</tr>
<tr>
<td>Farad</td>
<td>Unit of capacitance whereby a charge of one coulomb produces a one volt potential difference.</td>
</tr>
<tr>
<td>FCC</td>
<td>Federal Communications Commission (USA).</td>
</tr>
<tr>
<td>FCS</td>
<td>Frame Check Sequence. A general term given to the additional bits appended to a transmitted frame or message by the source to enable the receiver to detect possible transmission errors.</td>
</tr>
<tr>
<td>FDM</td>
<td>Frequency Division Multiplexer. A device that divides the available transmission frequency range in narrower bands, each of which is used for a separate channel.</td>
</tr>
<tr>
<td>Feedback</td>
<td>A part of the output signal being fed back to the input of the amplifier circuit.</td>
</tr>
<tr>
<td>Field</td>
<td>One half of a video image (frame) consisting of 312.5 lines (for PAL). There are two fields in a frame. Each is shown alternately every 1/25 of a second (for PAL).</td>
</tr>
<tr>
<td>FIFO</td>
<td>First in, First Out.</td>
</tr>
<tr>
<td>Filled Cable</td>
<td>A telephone cable construction in which the cable core is filled with a material that will prevent moisture from entering or passing along the cable.</td>
</tr>
<tr>
<td>FIP</td>
<td>Factory Instrumentation Protocol.</td>
</tr>
<tr>
<td>Firmware</td>
<td>A computer program or software stored permanently in PROM or ROM or semi-permanently in EPROM.</td>
</tr>
<tr>
<td>Flame Retardancy</td>
<td>The ability of a material not to propagate flame once the flame source is removed.</td>
</tr>
<tr>
<td>Floating</td>
<td>An electrical circuit that is above the earth potential.</td>
</tr>
<tr>
<td>Flow Control</td>
<td>The procedure for regulating the flow of data between two devices preventing the loss of data once a device's buffer has reached its capacity.</td>
</tr>
<tr>
<td>Frame</td>
<td>A full video image comprising two fields. A PAL frame has a total of 625 lines (an NTSC frame has 525 lines).</td>
</tr>
<tr>
<td>Frame</td>
<td>The unit of information transferred across a data link. Typically, there are control frames for link management and information frames for the transfer of message data.</td>
</tr>
</tbody>
</table>
Ground  An electrically neutral circuit having the same potential as the earth. A reference point for an electrical system also intended for safety purposes.

Half Duplex  Transmissions in either direction, but not simultaneously.

Half Power Point  The point in a Power versus frequency curve which is half the power level of the peak power (also called the 3dB point).

Hamming Distance  A measure of the effectiveness of error checking. The higher the Hamming Distance (HD) index, the safer is the data transmission.

Handshaking  Exchange of predetermined signals between two devices establishing a connection.

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Handshake Lines  Dedicated signals which allow two different devices to exchange data under asynchronous hardware control.

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Power Systems Protection, Power Quality, Substation Automation

**ISDN**
Integrated Services Digital Network. A fairly recent generation of worldwide telecommunications networks that utilize digital techniques for both transmission and switching. It supports both voice and data communications.

**ISO**
International Standards Organisation.

**Isolation**
Electrical separation of two circuits. For example, optical isolation allows a high-voltage signal to be transferred to a low-voltage input without electrical interactions.

**Isotropic Antenna**
A reference antenna that radiates energy in all directions from a point source.

**ISR**
Interrupt Service Routine. See Interrupt Handler.

**ITU**
International Telecommunications Union.

**Jabber**
Garbage that is transmitted when a LAN node fails and then continuously transmits.

**Jumper**
A wire connecting one or more pins (on the one end of a cable only, for example).

**k (kilo)**
Typically multiples of a thousand (e.g., 1 kilometer = 1000 meters)

**K**
In computer terminology, a K is $2^{10}=1024$. This distinguishes it from the SI unit k (kilo) which is 1000.

**LAN**
Local Area Network. A data communications system confined to a limited geographic area typically about 10 kms with moderate to high data rates (100kbps to 50 Mbps). Some type of switching technology is used, but common carrier circuits are not used.

**LCD**
Liquid Crystal Display. A low power display system used on many laptops and other digital equipment.

**LDM**
Limited Distance Modem. A signal converter which conditions and boosts a digital signal so that it may be transmitted further than a standard EIA-232 signal.

**Leased (or Private) Line**
A private telephone line without inter-exchange switching arrangements.

**LED**
Light Emitting Diode. A semi-conductor light source that emits visible light or infra red radiation.

**LF**
Line Feed (ASCII Control-J).

**Line Driver**
A signal converter that conditions a signal to ensure reliable transmission over an extended distance.

**Line Turnaround**
The reversal of transmission direction from transmitter to receiver or vice versa when a half duplex circuit is used.

**Linearity**
A relationship where the output is directly proportional to the input.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>MAP</td>
<td>Manufacturing Automation Protocol. A suite of network protocols originated by General Motors which follow the seven layers of the OSI model. A reduced implementation is referred to as a mini-MAP.</td>
</tr>
<tr>
<td>Mark</td>
<td>This is equivalent to a binary 1.</td>
</tr>
<tr>
<td>Mask</td>
<td>A structure covering certain portions of a photo-sensitive medium during photographic processing.</td>
</tr>
<tr>
<td>Masking</td>
<td>Setting portions of an image at a constant value, either black or white. Also the process of outlining an image and then matching it to test images.</td>
</tr>
<tr>
<td>Master/Slave</td>
<td>Bus access method whereby the right to transmit is assigned to one device only, the Master, and all the other devices, the Slaves may only transmit when requested.</td>
</tr>
<tr>
<td>Master Oscillator</td>
<td>The primary oscillator for controlling a transmitter or receiver frequency. The various types are: Variable Frequency Oscillator (VFO); Variable Crystal Oscillator (VXO); Permeability Tuned Oscillator (PTO); Phase Locked Loop (PLL); Linear Master Oscillator (LMO) or frequency synthesizer.</td>
</tr>
<tr>
<td>Media Access Unit</td>
<td>Referred to often as MAU. This is the Ethernet transceiver unit situated on the coaxial cable which then connects to the terminal with a drop cable.</td>
</tr>
<tr>
<td>Microwave</td>
<td>AC signals having frequencies of 1 GHz or more.</td>
</tr>
<tr>
<td>MIPS</td>
<td>Million Instructions per second.</td>
</tr>
<tr>
<td>MMS</td>
<td>Manufacturing Message Services. A protocol entity forming part of the application layer. It is intended for use specifically in the manufacturing or process control industry. It enables a supervisory computer to control the operation of a distributed community of computer based devices.</td>
</tr>
<tr>
<td>Modem</td>
<td>MODulator - DEModulator. A device used to convert serial digital data from a transmitting terminal to a signal suitable for transmission over a telephone channel or to recover the transmitted signal to serial digital data for the receiving terminal.</td>
</tr>
<tr>
<td>Modem Eliminator</td>
<td>A device used to connect a local terminal and a computer port in lieu of the pair of modems to which they would ordinarily connect, allow DTE to DTE data and control signal connections otherwise not easily achieved by standard cables or connecters.</td>
</tr>
<tr>
<td>Modulation Index</td>
<td>The ratio of the frequency deviation of the modulated wave to the frequency of the modulating signal.</td>
</tr>
<tr>
<td>Morphology</td>
<td>The study of a structure/shape or form of an object in an image.</td>
</tr>
<tr>
<td>MOS</td>
<td>Metal Oxide Semiconductor.</td>
</tr>
<tr>
<td>MOV</td>
<td>Metal Oxide Varistor.</td>
</tr>
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</table>
### Power Systems Protection, Power Quality, Substation Automation

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<th>Term</th>
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<tbody>
<tr>
<td>MSB</td>
<td>Most Significant Byte or Most Significant Bit.</td>
</tr>
<tr>
<td>MTBF</td>
<td>Mean Time Between Failures.</td>
</tr>
<tr>
<td>MTTR</td>
<td>Mean Time To Repair.</td>
</tr>
<tr>
<td>Multidrop</td>
<td>A single communication line or bus used to connect three or more points.</td>
</tr>
<tr>
<td>Multiplexer (MUX)</td>
<td>A device used for division of a communication link into two or more channels, either by using frequency division or time division.</td>
</tr>
<tr>
<td>Multiplexer</td>
<td>A technique in which multiple signals are combined into one channel. They can then be demultiplexed back into the original components.</td>
</tr>
<tr>
<td>NAK</td>
<td>Negative Acknowledge (ASCII Control-U).</td>
</tr>
<tr>
<td>Narrowband</td>
<td>A device that can only operate over a narrow band of frequencies.</td>
</tr>
<tr>
<td>Negative True Logic</td>
<td>The inversion of the normal logic where the negative state is considered to be TRUE (or 1) and the positive voltage state is considered to be FALSE (or 0).</td>
</tr>
<tr>
<td>Network Layer</td>
<td>Layer 3 in the OSI model; the logical network entity that services the transport layer responsible for ensuring that data passed to it from the transport layer is routed and delivered throughout the network.</td>
</tr>
<tr>
<td>Network Architecture</td>
<td>A set of design principles including the organisation of functions and the description of data formats and procedures used as the basis for the design and implementation of a network (ISO).</td>
</tr>
<tr>
<td>Network</td>
<td>An interconnected group of nodes or stations.</td>
</tr>
<tr>
<td>Network Topology</td>
<td>The physical and logical relationship of nodes in a network; the schematic arrangement of the links and nodes of a network typically in the form of a star, ring, tree or bus topology.</td>
</tr>
<tr>
<td>NMRR</td>
<td>Normal Mode Rejection Ratio - The ability of a board to filter out noise from external sources, such as AC power lines. NMRR filtering compensates for transient changes in the incoming signal to provide greater accuracy. The higher the NMRR, the better the filtering of incoming data will be.</td>
</tr>
<tr>
<td>Node</td>
<td>A point of interconnection to a network.</td>
</tr>
<tr>
<td>Noise</td>
<td>A term given to the extraneous electrical signals that may be generated or picked up in a transmission line. If the noise signal is large compared with the data carrying signal, the latter may be corrupted resulting in transmission errors.</td>
</tr>
<tr>
<td>Non-linearity</td>
<td>A type of error in which the output from a device does not relate to the input in a linear manner.</td>
</tr>
<tr>
<td>NRZ</td>
<td>Non Return to Zero. Pulses in alternating directions for successive 1 bits but no change from existing signal voltage for 0 bits.</td>
</tr>
<tr>
<td>NRZI</td>
<td>Non Return to Zero Inverted.</td>
</tr>
<tr>
<td>NTSC</td>
<td>National Television System Committee (USA). A television standard specifying 525 lines and 60 fields per second.</td>
</tr>
<tr>
<td>Null Modem</td>
<td>A device that connects two DTE devices directly by emulating the physical connections of a DCE device.</td>
</tr>
<tr>
<td>Number of Channels</td>
<td>This is the number of input lines a board can sample. Single-ended inputs share the same ground connection, while differential inputs have individual two-wire inputs for each incoming signal, allowing greater accuracy and signal isolation. See also multiplexer.</td>
</tr>
<tr>
<td>Nyquist Sampling Theory</td>
<td>In order to recover all the information about a specified signal it must be sampled at twice the maximum frequency component of the specified signal.</td>
</tr>
<tr>
<td>OCR</td>
<td>Optical Character Recognition, optical character reader.</td>
</tr>
<tr>
<td>OHM</td>
<td>Unit of resistance such that a constant current of one ampere produces a potential difference of one volt across a conductor.</td>
</tr>
<tr>
<td>OLUT</td>
<td>Output Look-Up Table.</td>
</tr>
<tr>
<td>On-board Memory</td>
<td>Incoming data is stored in on-board memory before being dumped into the PC’s memory. On a high-speed board, data is acquired at a much higher rate than can be written into PC memory, so it is stored in the on-board buffer memory.</td>
</tr>
<tr>
<td>Optical Isolation</td>
<td>Two networks with no electrical continuity in their connection because an optoelectronic transmitter and receiver has been used.</td>
</tr>
<tr>
<td>OR</td>
<td>Outside Radius.</td>
</tr>
<tr>
<td>OSI</td>
<td>Open Systems Interconnection. A set of defined protocol layers with a standardised interface which allows equipment from different manufacturers to be connected.</td>
</tr>
<tr>
<td>Output</td>
<td>An analog or digital output control type signal from the PC to the external 'real world'.</td>
</tr>
<tr>
<td>Overlay</td>
<td>One video signal superimposed on another, as in the case of computer-generated text over a video picture.</td>
</tr>
<tr>
<td>Packet</td>
<td>A group of bits (including data and call control signals) transmitted as a whole on a packet switching network. Usually smaller than a transmission block.</td>
</tr>
<tr>
<td>PAD</td>
<td>Packet Access Device. An interface between a terminal or computer and a packet switching network.</td>
</tr>
<tr>
<td>PAL</td>
<td>Phase Alternating Lines. This is the television standard used in Europe and Australia. The PAL standard is 25 frames per second with 625 lines.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>Power Systems Protection, Power Quality, Substation Automation</td>
<td></td>
</tr>
<tr>
<td>PIA</td>
<td>Peripheral Interface Adapter. Also referred to as PPI (Programmable Peripheral Interface).</td>
</tr>
<tr>
<td>Pixel</td>
<td>One element of a digitised image, sometimes called picture element, or pel.</td>
</tr>
<tr>
<td>PLC</td>
<td>Programmable Logic Controller.</td>
</tr>
<tr>
<td>PLL</td>
<td>Phase Locked Loop</td>
</tr>
<tr>
<td>Point to Point</td>
<td>A connection between only two items of equipment.</td>
</tr>
<tr>
<td>Polar Orbit</td>
<td>The path followed when the orbital plane includes the north and south poles.</td>
</tr>
<tr>
<td>Polarisation</td>
<td>The direction of an electric field radiated from an antenna.</td>
</tr>
<tr>
<td>Polling</td>
<td>A means of controlling I/O devices on a multipoint line in which the CPU queries ('polls') the devices at regular intervals to check for data awaiting transfer (to the CPU). Slower and less efficient than interrupt driven I/O operations.</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>A family of insulators derived from the polymerisation of ethylene gas and characterised by outstanding electrical properties, including high IR, low dielectric constant, and low dielectric loss across the frequency spectrum.</td>
</tr>
<tr>
<td>Polyvinyl Chloride (PVC)</td>
<td>A general purpose family of insulations whose basic constituent is polyvinyl chloride or its copolymer with vinyl acetate. Plasticisers, stabilisers, pigments and fillers are added to improve mechanical and/or electrical properties of this material.</td>
</tr>
<tr>
<td>Port</td>
<td>A place of access to a device or network, used for input/output of digital and analog signals.</td>
</tr>
<tr>
<td>Pretrigger</td>
<td>A modulation technique (also referred to as PSK) used to convert binary data into an analog form comprising a single sinusoidal frequency signal whose phase varies according to the data being transmitted. Boards with 'pretrigger' capability keep a continuous buffer filled with data, so when the trigger conditions are met, the sample includes the data leading up to the trigger condition.</td>
</tr>
<tr>
<td>Profibus</td>
<td>Process Field Bus developed by a consortium of mainly German companies with the aim of standardisation.</td>
</tr>
<tr>
<td>Program I/O</td>
<td>The standard method of memory access, where each piece of data is assigned to a variable and stored individually by the PC's processor.</td>
</tr>
</tbody>
</table>
### Programmable Gain
Using an amplifier chip on an A/D board, the incoming analog signal is increased by the gain multiplication factor. For example, if the input signal is in the range of -250 mV to +250 mV, the voltage after the amplifier chip set to a gain of 10 would be -2.5 V to +2.5 V.

### PROM
Programmable Read Only Memory. This is programmed by the manufacturer as a fixed data or program which cannot easily be changed by the user.

### Protocol Entity
The code that controls the operation of a protocol layer.

### Protocol
A formal set of conventions governing the formatting, control procedures and relative timing of message exchange between two communicating systems.

### PSDN
Public Switched Data Network. Any switching data communications system, such as Telex and public telephone networks, which provides circuit switching to many customers.

### PSTN
Public Switched Telephone Network. This is the term used to describe the (analogue) public telephone network.

### PTT
Post, Telephone and Telecommunications Authority.

### Public Switched Network
Any switching communications system - such as Telex and public telephone networks - that provides circuit switching to many customers.

### Pulse Input
A square wave input from a real world device such as a flow meter, which sends pulses proportional to the flow rate.

### QAM
Quadrature Amplitude Modulation.

### QPSK
Quadrature Phase Shift Keying.

### Quagi
An antenna consisting of both full wavelength loops (quad) and Yagi elements.

### R/W
Read/Write.

### RAM
Random Access Memory. Semiconductor read/write volatile memory. Data is lost if the power is turned off.

### RAMDAC
Random Access Memory Digital-to-Analog Converter.

### Range
The difference between the upper and lower limits of the measured value.

### Range Select
The full-scale range a board uses is selected by one of three methods: through the appropriate software, by a hardware jumper on the board, or through the use of an external reference voltage.

### Raster
The pattern of lines traced by rectilinear scanning in display systems.

### Reactance
The opposition offered to the flow of alternating current by inductance or capacitance of a component or circuit.
<p>| <strong>ROM</strong> | Read Only Memory. Computer memory in which data can be routinely read but written to only once using special means when the ROM is manufactured. A ROM is used for storing data or programs on a permanent basis. |
| <strong>Router</strong> | A linking device between network segments which may differ in Layers 1, 2a and 2b of the ISO/OSI Reference Model. |
| <strong>RS</strong> | Recommended Standard, for example, RS-232C. More recent designations use EIA, for example, EIA-232C. |
| <strong>RS-232C</strong> | Interface between DTE and DCE, employing serial binary data exchange. Typical maximum specifications are 50 feet (15m) at 19200 baud. |
| <strong>RS-422</strong> | Interface between DTE and DCE, employing the electrical characteristics of balanced voltage interface circuits. |
| <strong>RS-423</strong> | Interface between DTE and DCE, employing the electrical characteristics of unbalanced voltage digital interface circuits. |
| <strong>RS-449</strong> | General purpose 37-pin and 9-pin interface for DCE and DTE employing serial binary interchange. |
| <strong>RS-485</strong> | The recommended standard of the EIA that specifies the electrical characteristics of drivers and receivers for use in balanced digital multipoint systems. |
| <strong>RTU</strong> | Remote Terminal Unit. Terminal Unit situated remotely from the main control system. |
| <strong>S-Video</strong> | The luminance and chrominance elements of a video signal are isolated from each other, resulting in a far cleaner image with greater resolution. |
| <strong>SAA</strong> | Standards Association of Australia. |
| <strong>SAP</strong> | Service Access Point. |
| <strong>SDLIC</strong> | Synchronous Data Link Control: IBM standard protocol superseding the biynchronous standard. |
| <strong>Selectivity</strong> | A measure of the performance of a circuit in distinguishing the desired signal from those at other frequencies. |
| <strong>Self-calibrating</strong> | A self-calibrating board has an extremely stable on-board reference which is used to calibrate A/D and D/A circuits for higher accuracy. |
| <strong>Self-diagnostics</strong> | On-board diagnostic routine which tests most, if not all, of a board’s functions at power-up or on request. |
| <strong>Serial Transmission</strong> | The most common transmission mode in which information bits are sent sequentially on a single data channel. |
| <strong>Session Layer</strong> | Layer 5 of the ISO/OSI Reference Model, concerned with the establishment of a logical connection between two application entities and with controlling the dialogue (message exchange) between them. |
| <strong>Shielding</strong> | The process of protecting an instrument or cable from external noise (or sometimes protecting the surrounding environment of the cable from signals within the cable.) |
| <strong>Short Haul Modem</strong> | A signal converter which conditions a digital signal to ensure reliable transmission over DC continuous private line metallic circuits, without interfering with adjacent pairs of wires in the same telephone cables. |
| <strong>Shutter</strong> | A mechanical or electronic device used to control the amount of time a light-sensitive material is exposed to radiation. |
| <strong>SI</strong> | International metric system of units (Système Internationale). |
| <strong>Sidereal Day</strong> | The period of an earth's rotation with respect to the stars. |
| <strong>Signal to Noise Ratio</strong> | The ratio of signal strength to the level of noise. |
| <strong>Signal Conditioning</strong> | Pre-processing of a signal to bring it up to an acceptable quality level for further processing by a more general purpose analog input system. |
| <strong>Signal to Noise Ratio</strong> | The ratio of signal strength to the level of noise. |
| <strong>Simplex Transmission</strong> | Data transmission in one direction only. |
| <strong>Simultaneous Sampling</strong> | The ability to acquire and store multiple signals at exactly the same moment. Sample-to-sample inaccuracy is typically measured in nanoseconds. |
| <strong>Slew Rate</strong> | This is defined as the rate at which the voltage changes from one value to another. |
| <strong>Smart Sensors</strong> | A transducer (or sensor) with an on-board microprocessor to pre-process input signals to the transducer. It also has the capability of communicating digitally back to a central control station. |
| <strong>SNA</strong> | Systems Network Architecture. |
| <strong>SNR</strong> | Signal to Noise Ratio. |
| <strong>Software Drivers</strong> | Typically a set of programs or subroutines allowing the user to control basic board functions, such as setup and data acquisition. These can be incorporated into user-written programs to create a simple but functional DAS system. Many boards come with drivers supplied. |</p>
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<tbody>
<tr>
<td><strong>Sync</strong></td>
<td>Software Trigger: Software control of data acquisition triggering. Most boards are designed for software control.</td>
</tr>
<tr>
<td><strong>Synchronisation</strong></td>
<td>SOH: Start of Header (ASCII Control-A).</td>
</tr>
<tr>
<td><strong>Synchronous Transmission</strong></td>
<td>Space: Absence of signal. This is equivalent to a binary zero.</td>
</tr>
<tr>
<td><strong>Talker</strong></td>
<td>Spark Test: A test designed to locate imperfections (usually pin-holes) in the insulation of a wire or cable by application of a voltage for a very short period of time while the wire is being drawn through the electrode field.</td>
</tr>
<tr>
<td><strong>Spatial Resolution</strong></td>
<td>Synchronisation: The co-ordination of the activities of several circuit elements.</td>
</tr>
<tr>
<td><strong>Spatial Filtering</strong></td>
<td>Synchronous Transmission: Transmission in which data bits are sent at a fixed rate, with the transmitter and receiver synchronised. Synchronised transmission eliminates the need for start and stop bits.</td>
</tr>
<tr>
<td><strong>Spatial Purity</strong></td>
<td>Talker: A device on the GPIB bus that simply sends information onto the bus without actually controlling the bus.</td>
</tr>
<tr>
<td><strong>Spectral Resolution</strong></td>
<td>Talker: A circuit comprising inductance and capacitance which can store electrical energy over a finite band of frequencies.</td>
</tr>
<tr>
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<tr>
<td><strong>Spatial Filtering</strong></td>
<td>Talker: The relative quality of a signal measured by the absence of harmonics, spurious signals and noise.</td>
</tr>
<tr>
<td><strong>Spatial Purity</strong></td>
<td>Talker: In image processing, the enhancement of an image by increasing or decreasing its spatial frequencies.</td>
</tr>
<tr>
<td><strong>Spatial Purity</strong></td>
<td>Talker: Text Mode Signals from the hardware to the display device are only interpreted as text characters.</td>
</tr>
<tr>
<td><strong>Spatial Purity</strong></td>
<td>Thresholding: The process of defining a specific intensity level for determining which of two values will be assigned to each pixel in binary processing. If the pixel's brightness is above the threshold level, it will appear in white in the image; if it is below the threshold level, it will appear black.</td>
</tr>
<tr>
<td><strong>Spatial Purity</strong></td>
<td>TIA: Telecommunications Industry Association.</td>
</tr>
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<td>TIA: Telecommunications Industry Association.</td>
</tr>
</tbody>
</table>
The IDC Engineers Pocket Guide

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**Time Division**
The process of transmitting multiple signals over a single channel by multiplexing taking samples of each signal in a repetitive time sequenced fashion.

**Time Sharing**
A method of computer operation that allows several interactive terminals to use one computer.

**Time Domain**
The display of electrical quantities versus time.

**Token Ring**
Collision free, deterministic bus access method as per IEEE 802.3 ring topology.

**TOP**
Technical Office Protocol. A user association in USA which is primarily concerned with open communications in offices.

**Topology**
Physical configuration of network nodes, e.g. bus, ring, star, tree.

**Transceiver**
A combination of transmitter and receiver.

**Transducer**
Any device that generates an electrical signal from real-world physical measurements. Examples are LVDTs, strain gauges, thermocouples and RTDs. A generic term for sensors and their supporting circuitry.

**Transient**
An abrupt change in voltage of short duration.

**Transmission Line**
One or more conductors used to convey electrical energy from one point to another.

**Transport Layer**
Layer 4 of the ISO/OSI Reference Model, concerned with providing a network independent reliable message interchange service to the application oriented layers (layers 5 through 7).

**Trigger**
A rising edge at an 8254 timer/counter's gate input.

**Trunk**
A single circuit between two points, both of which are switching centres or individual distribution points. A trunk usually handles many channels simultaneously.

**Twisted Pair**
A data transmission medium, consisting of two insulated copper wires twisted together. This improves its immunity to interference from nearby electrical sources that may corrupt the transmitted signal.

**UART**
Universal Asynchronous Receiver/Transmitter. An electronic circuit that translates the data format between a parallel representation, within a computer, and the serial method of transmitting data over a communications line.

**UHF**
Ultra High Frequency.

**Unbalanced Circuit**
A transmission line in which voltages on the two conductors are unequal with respect to ground e.g. a coaxial cable.

**Unipolar Inputs**
When set to accept a unipolar signal, the channel detects and converts only positive voltages. (Example: 0 to +10 V).

**Unloaded Line**
A line with no loaded coils that reduce line loss at audio frequencies.

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Power Systems Protection, Power Quality, Substation Automation

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**Upconverter**
A device used to translate a modulated signal to a higher band of frequencies.

**Uplink**
The path from an earth station to a satellite.

**USRT**
Universal Synchronous Receiver/Transmitter. See UART.

**UTP**
Unshielded Twisted Pair.

**V.35**
CCITT standard governing the transmission at 48 kbps over 60 to 108 kHz group band circuits.

**VCO**
Voltage controlled oscillator. Uses variable DC applied to tuning diodes to change their junction capacitances. This results in the output frequency being dependent on the input voltage.

**Velocity of Propagation**
The speed of an electrical signal down a length of cable compared to speed in free space expressed as a percentage.

**VFD**
Virtual Field Device. A software image of a field device describing the objects supplied by it e.g. measured data, events, status etc which can be accessed by another node on the network.

**VGA**
Video Graphics Array. This standard utilizes analog signals only (between 0 and 1 V) offering a resolution of 640 by 480 pixels, a palette of 256 colors out of 256000 colors and the ability to display 16 colors at the same time.

**VHF**
Very High Frequency.

**Vidicon**
A small television tube originally developed for closed-circuit television. It is about one inch (2.54 cm) in diameter and five inches (12.7 cm) long. Its controls are relatively simple and can be operated by unskilled personnel. The Vidicon is widely used in broadcast service.

**Volatile Memory**
A storage medium that loses all data when power is removed.

**Voltage Rating**
The highest voltage that may be continuously applied to a wire in conformance with standards of specifications.

**VRAM**
Volatile Random Access Memory. See RAM.

**VSD**
Variable Speed Drive.

**VT**
Virtual Terminal.

**WAN**
Wide Area Network.

**Waveguide**
A hollow conducting tube used to convey microwave energy.

**Wedge Filter**
An optical filter so constructed that the density increases progressively from one end to the other, or angularly around a circular disk.

**Word**
The standard number of bits that a processor or memory manipulates at one time. Typically, a word has 16 bits.
Appendix B
Units and Abbreviations

### Table A.1
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Prefix</th>
<th>Factor by which unit is multiplied</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>metre</td>
<td>10^6</td>
</tr>
<tr>
<td>kg</td>
<td>kilogram</td>
<td>10^3</td>
</tr>
<tr>
<td>s</td>
<td>second</td>
<td>10</td>
</tr>
<tr>
<td>A</td>
<td>ampere</td>
<td>10^-3</td>
</tr>
<tr>
<td>K</td>
<td>kelvin</td>
<td>10^-10</td>
</tr>
<tr>
<td>cd</td>
<td>candela</td>
<td>10^-6</td>
</tr>
</tbody>
</table>

### Table A.2
Decimal Prefixes

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Factor by which unit is multiplied</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>10^12</td>
</tr>
<tr>
<td>G</td>
<td>10^9</td>
</tr>
<tr>
<td>M</td>
<td>10^6</td>
</tr>
<tr>
<td>k</td>
<td>10^3</td>
</tr>
<tr>
<td>h</td>
<td>10^2</td>
</tr>
<tr>
<td>da</td>
<td>10</td>
</tr>
<tr>
<td>d</td>
<td>10^-1</td>
</tr>
<tr>
<td>c</td>
<td>10^-2</td>
</tr>
<tr>
<td>m</td>
<td>10^-3</td>
</tr>
<tr>
<td>µ</td>
<td>10^-6</td>
</tr>
<tr>
<td>n</td>
<td>10^-9</td>
</tr>
<tr>
<td>p</td>
<td>10^-12</td>
</tr>
</tbody>
</table>

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### Table A.6
Physical Constants

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Symbol</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avogadro's number</td>
<td>N</td>
<td>$6.023 \times 10^{23} / \text{kg mol}$</td>
</tr>
<tr>
<td>Bohr magneton</td>
<td>B</td>
<td>$9.27 \times 10^{-24} \text{A m}$</td>
</tr>
<tr>
<td>Boltzmann's constant</td>
<td>$k$</td>
<td>$1.380 \times 10^{-23} \text{J/°K}$</td>
</tr>
<tr>
<td>Stefan-Boltzmann constant</td>
<td>$\sigma$</td>
<td>$5.67 \times 10^{-8} \text{W/(m²K)}$</td>
</tr>
<tr>
<td>Characteristic impedance of free space</td>
<td>$Z_e$</td>
<td>$(\mu_0 E_0)^{1/2}/120\pi \Omega$</td>
</tr>
<tr>
<td>Electron volt</td>
<td>eV</td>
<td>$1.602 \times 10^{-19} \text{J}$</td>
</tr>
<tr>
<td>Electron charge</td>
<td>e</td>
<td>$1.602 \times 10^{-19} \text{C}$</td>
</tr>
<tr>
<td>Electronic rest mass</td>
<td>$m_e$</td>
<td>$9.109 \times 10^{-31} \text{kg}$</td>
</tr>
<tr>
<td>Electronic charge to mass ratio</td>
<td>$e/m_e$</td>
<td>$1.759 \times 10^{11} \text{C/kg}$</td>
</tr>
<tr>
<td>Faraday constant</td>
<td>F</td>
<td>$9.65 \times 10^{2} \text{C/\text{kg mol}}$</td>
</tr>
<tr>
<td>Permeability of free space</td>
<td>$\mu_0$</td>
<td>$4\pi \times 10^{-7} \text{H/m}$</td>
</tr>
<tr>
<td>Permittivity of free space</td>
<td>$\varepsilon_0$</td>
<td>$8.85 \times 10^{-12} \text{F/m}$</td>
</tr>
<tr>
<td>Planck's constant</td>
<td>$h$</td>
<td>$6.626 \times 10^{-34} \text{J s}$</td>
</tr>
<tr>
<td>Proton mass</td>
<td>$m_p$</td>
<td>$1.672 \times 10^{-27} \text{kg}$</td>
</tr>
<tr>
<td>Proton to electron mass ratio</td>
<td>$m_p/m_e$</td>
<td>$1835.6$</td>
</tr>
<tr>
<td>Standard gravitational acceleration</td>
<td>$g$</td>
<td>$9.80665 \text{m/s²}$</td>
</tr>
<tr>
<td>Universal constant of gravitation</td>
<td>$G$</td>
<td>$6.67 \times 10^{-11} \text{N m²/kg²}$</td>
</tr>
<tr>
<td>Universal gas constant</td>
<td>$P_0$</td>
<td>$8.314 \text{kJ/kg mol K}$</td>
</tr>
<tr>
<td>Velocity of light in vacuo</td>
<td>$c$</td>
<td>$2.9979 \times 10^{8} \text{m/s}$</td>
</tr>
<tr>
<td>Volume of 1 kg mol of ideal gas at 1 atm &amp; 0°C</td>
<td>-</td>
<td>$22.41 \text{m³}$</td>
</tr>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>$5/9(°F - 32)$</td>
</tr>
<tr>
<td>Temperature</td>
<td>K</td>
<td>$5/9(°F - 459.67)$</td>
</tr>
<tr>
<td>°C</td>
<td>$5/9°C + 273.15$</td>
<td></td>
</tr>
</tbody>
</table>

### Table A.3
Supplementary and Derived Units (electrical)

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Electrical unit</th>
<th>Symbol</th>
<th>Derived unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>potential</td>
<td>volt</td>
<td>V</td>
<td>W/A</td>
</tr>
<tr>
<td>resistance</td>
<td>ohm</td>
<td>Ω</td>
<td>V/A</td>
</tr>
<tr>
<td>charge</td>
<td>coulomb</td>
<td>C</td>
<td>A s</td>
</tr>
<tr>
<td>capacitance</td>
<td>farad</td>
<td>F</td>
<td>A s/V</td>
</tr>
<tr>
<td>electric field strength</td>
<td>-</td>
<td>V/m</td>
<td>-</td>
</tr>
<tr>
<td>electric flux density</td>
<td>-</td>
<td>C/m²</td>
<td>-</td>
</tr>
</tbody>
</table>

### Table A.4
Supplementary and Derived Unit (magnetic)

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Magnetic unit</th>
<th>Symbol</th>
<th>Derived unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>magnetic flux</td>
<td>weber</td>
<td>Wb</td>
<td>V s = Nm/A</td>
</tr>
<tr>
<td>inductance</td>
<td>henry</td>
<td>H</td>
<td>V s/A = Nm/A</td>
</tr>
<tr>
<td>magnetic field strength</td>
<td>-</td>
<td>A/m</td>
<td>-</td>
</tr>
<tr>
<td>magnetic flux density</td>
<td>tesla</td>
<td>T</td>
<td>Wb/m² = (N)/(A m)</td>
</tr>
</tbody>
</table>
### Appendix C
Commonly used Formulae

#### Symbols used in formulae

The symbols described in the following table are used in the formulae shown in the next section.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Velocity of sound</td>
<td>ms⁻¹</td>
</tr>
<tr>
<td>a</td>
<td>Acceleration</td>
<td>ms²</td>
</tr>
<tr>
<td>A</td>
<td>Area</td>
<td>m²</td>
</tr>
<tr>
<td>c</td>
<td>Velocity of light</td>
<td>ms⁻¹</td>
</tr>
<tr>
<td>C</td>
<td>Capacitance</td>
<td>F</td>
</tr>
<tr>
<td>D</td>
<td>Diameter</td>
<td>m</td>
</tr>
<tr>
<td>E</td>
<td>Young's modulus</td>
<td>Nm⁻²</td>
</tr>
<tr>
<td>f</td>
<td>Energy difference</td>
<td>J</td>
</tr>
<tr>
<td>f</td>
<td>Frequency</td>
<td>Hz</td>
</tr>
<tr>
<td>F</td>
<td>Force</td>
<td>N</td>
</tr>
<tr>
<td>H</td>
<td>Magnetising force magnetic field strength</td>
<td>Am⁻¹</td>
</tr>
<tr>
<td>I</td>
<td>Current</td>
<td>A</td>
</tr>
<tr>
<td>I</td>
<td>Moment of inertia</td>
<td>kgm²</td>
</tr>
<tr>
<td>k</td>
<td>Radius of gyration</td>
<td>m</td>
</tr>
<tr>
<td>kp</td>
<td>Pitch factor of winding</td>
<td>-</td>
</tr>
<tr>
<td>l</td>
<td>Length</td>
<td>m</td>
</tr>
<tr>
<td>l</td>
<td>Length of conductor</td>
<td>m</td>
</tr>
<tr>
<td>L</td>
<td>Inductance</td>
<td>H</td>
</tr>
<tr>
<td>m</td>
<td>Mass</td>
<td>kg</td>
</tr>
<tr>
<td>M</td>
<td>Momentum</td>
<td>Kg.m.s⁻²</td>
</tr>
<tr>
<td>n</td>
<td>Speed of rotation</td>
<td>rpm</td>
</tr>
<tr>
<td>N</td>
<td>Number of turns</td>
<td>-</td>
</tr>
<tr>
<td>p</td>
<td>Number of pole pairs</td>
<td>-</td>
</tr>
<tr>
<td>φ</td>
<td>Angle</td>
<td>radians</td>
</tr>
<tr>
<td>F</td>
<td>Magnetic flux, flux per pole</td>
<td>Wb</td>
</tr>
<tr>
<td>w</td>
<td>Angular Velocity</td>
<td>rad.s⁻¹</td>
</tr>
<tr>
<td>w₁</td>
<td>Natural frequency</td>
<td>rad.s⁻¹</td>
</tr>
<tr>
<td>w₂</td>
<td>Natural frequency</td>
<td>rad.s⁻¹</td>
</tr>
<tr>
<td>w₃</td>
<td>Damped natural frequency</td>
<td>rad.s⁻¹</td>
</tr>
</tbody>
</table>

### Symbols Description

- **Q**: Volumetric flow rate $m^3 s^{-1}$
- **Q**: Charge $C$
- **R**: Resistance $\Omega$
- **s**: Fractional slip -
- **t**: Time $s$
- **T**: Time Factor -
- **T**: Torque $Nm$
- **∆T**: Temperature (absolute) $K$
- **\( \Delta T \)**: Temperature difference $°C$
- **u**: Velocity $ms^{-1}$
- **v**: Velocity $ms^{-1}$
- **V**: Voltage $V$
- **V**: Volume $m^3$
- **x**: Distance (variables as in dx) $m$
- **Z**: Number of armature conductors -
- **Z**: Impedance $\Omega$
- **a**: Coefficient of volumetric expansion $Hm/(mK)$
- **a**: Resistance coefficient $\Omega K^{-1}$
- **b**: Coefficient of volumetric expansion $K^{-1}$
- **\( \varepsilon_0 \)**: Permittivity of free space $F m^{-1}$
- **\( \varepsilon_r \)**: Permittivity-relative -
- **\( \mu_0 \)**: Permeability of free space $H m^{-1}$
- **\( \mu_r \)**: Permeability-relative -
- **\( r_\alpha \)**: Resistivity $\Omega m^3$
- **r**: Density $kg/m^3$
- **s**: Stefan-Boltzmann constant $W m^{-2} K^{-4}$
- **e**: Angle radians
- **F**: Magnetic flux, flux per pole $Wb$
- **w**: Angular Velocity $rad.s^{-1}$
- **w₁**: Natural frequency $rad.s^{-1}$
- **w₂**: Natural frequency $rad.s^{-1}$
- **w₃**: Damped natural frequency $rad.s^{-1}$
Resistors in parallel:

\[ R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots} \]

Inductance

\[ V = -L \frac{dl}{dt} \]

\[ i = -\frac{V}{L} \]

\[ L = N^2 \mu_0 \mu_r \frac{a}{l} \]

for LR circuit decay, stored energy is calculated as follows:

\[ Energy = \frac{1}{2} L I^2 \]

Capacitance

\[ Q = CV = \int idt \]

\[ i = \frac{dQ}{dt} = C \frac{dV}{dt} \]
For a solenoid:

\[ H = \frac{NI}{l} \]
Magnetism

\[ H = \frac{B}{\mu_0 \mu_r} \]

For a magnetic circuit:

\[ B = \frac{\Phi}{a} \]

Stored energy density:

\[ \text{Energy} = \frac{1}{2} HB = \frac{1}{2} \frac{B^2}{\mu_0} \]

AC Circuits

\[ V_{\text{rms}} = \sqrt{\frac{2}{\pi}} V_{\text{peak}} \]

\[ Z = \left( R^2 + \left( wL - \frac{1}{wC} \right)^2 \right)^{\frac{1}{2}} \]

\[ Z = R = jwL + \frac{1}{jwC} \]

\[ \cos \phi = \frac{R}{Z} \]

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Sound

Note that decibels are not units as such but a ratio of voltages, currents and power, for example:

\[ dB = 10 \log_{10} \frac{P_1}{P_2} \]

where \( P_1, P_2 \) are the power levels:

\[ dB = 20 \log_{10} \frac{V_1}{V_2} \]

For differing input and output impedances the following formula is appropriate:

\[ dB = 20 \log_{10} \frac{V_1}{V_2} + 10 \log_{10} \frac{Z_2}{Z_1} \]

Where \( V_1, V_2 \) are the voltages \( Z_1, Z_2 \) are the impedances.
Appendix D
Resistor Color Coding

Resistor values are calculated according to the following color coding:

<table>
<thead>
<tr>
<th>Color on resistor</th>
<th>Value allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
</tr>
<tr>
<td>Red</td>
<td>2</td>
</tr>
<tr>
<td>Orange</td>
<td>3</td>
</tr>
<tr>
<td>Yellow</td>
<td>4</td>
</tr>
<tr>
<td>Green</td>
<td>5</td>
</tr>
<tr>
<td>Blue</td>
<td>6</td>
</tr>
<tr>
<td>Violet/Purple</td>
<td>7</td>
</tr>
<tr>
<td>Grey</td>
<td>8</td>
</tr>
<tr>
<td>White</td>
<td>9</td>
</tr>
</tbody>
</table>

Table C.1

Common Band Colors

Resistors have the following two major groupings of color coding:

Tolerance Band Colours - 1%

- ±1% - Brown
- ±2% - Red
- ±5% - Gold
- ±10% - Silver
- ±20% - No Band (or Black)

Tolerance Band Colours - 5%

- 2% - Red
- 5% - Gold
- 10% - Silver
- 20% - No Band

Figure C.1
Color coding for tolerance resistors
Who is IDC Technologies

IDC Technologies is a specialist in the field of industrial communications, telecommunications, automation and control and has been providing high quality training on an international basis for more than ten years.

IDC Technologies consists of an enthusiastic team of professional engineers and support staff who are committed to providing the highest quality in their consulting and training services.

The Benefits to You of Technical Training

The technological world today presents tremendous challenges to engineers, scientists and technicians in keeping up to date and taking advantage of the latest developments in the key technology areas.

The immediate benefits of attending an IDC Technologies workshop are:
- Gain practical hands-on experience
- Enhance your expertise and credibility
- Save $$$ for your company
- Obtain state of the art knowledge for your company
- Learn new approaches to troubleshooting
- Improve your future career prospects

The IDC Technologies Approach to Training

All workshops have been carefully structured to ensure that attendees gain maximum benefits. A combination of carefully designed training software, hardware and well written documentation, together with multimedia techniques ensure that the workshops are presented in an interesting, stimulating and logical fashion.

IDC Technologies has structured a number of workshops to cover the major areas of technology. These workshops are presented by instructors who are experts in their fields, and have been attended by thousands of engineers, technicians and scientists world-wide, who have given excellent reviews.

The IDC Technologies team of professional engineers is constantly reviewing the workshops and talking to industry leaders in these fields, thus keeping the workshops topical and up to date.

Technical Training Workshops

IDC is continually developing high quality state of the art workshops aimed at assisting engineers, technicians and scientists. Current workshops include:

DATA COMMUNICATIONS & NETWORKING
- Best Practice in Industrial Data Communications
- Practical Data Communications & Networking for Engineers and Technicians
- Practical DNP3, 6087.0.5 & Modern SCADA Communication Systems
- Practical Troubleshooting & Problem Solving of Ethernet Networks
- Practical Fieldbus and Device Networks for Engineers and Technicians
- Practical Fieldbus, DeviceNet and Ethernet for Industry
- Practical Use and Understanding of Foundation Fieldbus for Engineers and Technicians
- Practical Fibre Optics for Engineers and Technicians
- Practical Industrial Communication Protocols
- Practical Troubleshooting & Problem Solving of Industrial Data Communications
- Practical Troubleshooting, Design & Selection of Industrial Fibre Optic Systems for Industry
- Practical Industrial Networking for Engineers & Technicians
- Practical Industrial Ethernet & TCP/IP Networks
- Practical Local Area Networks for Engineers and Technicians
- Practical Routers & Switches (including TCP/IP and Ethernet) for Engineers & Technicians
- Practical TCP/IP and Ethernet Networking for Industry
- Practical Fundamentals of Telecommunications and Wireless Communications
- Practical Radio & Telemetry Systems for Industry
- Practical TCP/IP Troubleshooting & Problem Solving for Industry
- Practical Troubleshooting of TCP/IP Networks
- Practical Fundamentals of Voice over IP (VOIP) for Engineers and Technicians
- Wireless Networking and Radio Telemetry Systems for Industry
- Wireless Networking Technologies for Industry

ELECTRICAL
- Practical Maintenance & Troubleshooting of Battery Power Supplies
- Practical Electrical Network Automation & Communication Systems
- Safe Operation & Maintenance of Circuit Breakers and Switchgear
- Troubleshooting, Maintenance & Protection of AC Electrical Motors and Drives
- Practical Troubleshooting of Electrical Equipment and Control Circuits
- Practical Earthing, Bonding, Lightning & Surge Protection
- Practical Distribution & Substation Automation for Electrical Power Systems
- Practical Solutions to Harmonics in Power Distribution
- Practical High Voltage Safety Operating Procedures for Engineers and Technicians
The IDC Engineers Pocket Guide

- Practical Electrical Wiring Standards - National Rules for Electrical Installations
- Lightning, Surge Protection and Earthing of Electrical & Electronic Systems
- Practical Power Distribution
- Practical Power Quality: Problems & Solutions

ELECTRONICS
- Practical Digital Signal Processing Systems for Engineers and Technicians
- Practical Embedded Controllers: Troubleshooting and Design
- Practical EMC and EMI Control for Engineers and Technicians
- Practical Industrial Electronics for Engineers and Technicians
- Practical Image Processing and Applications
- Power Electronics and Variable Speed Drives: Troubleshooting & Maintenance
- Practical Shielding, EMC/EMI Noise Reduction, Earthing and Circuit Board Layout

INFORMATION TECHNOLOGY
- Practical Web-Site Development & E-Commerce Systems for Industry
- Industrial Network Security for SCADA, Automation, Process Control & PLC Systems
- SNMP Network Management: The Essentials
- VisualBasic Programming for Industrial Automation, Process Control & SCADA Systems

INSTRUMENTATION, AUTOMATION & PROCESS CONTROL
- Practical Analytical Instrumentation in On-Line Applications
- Practical Alarm Systems Management for Engineers and Technicians
- Practical Programmable Logic Controller’s (PLCs) for Automation and Process Control
- Practical Batch Management & Control (Including S88) for Industry
- Practical Boiler Control and Instrumentation for Engineers and Technicians
- Practical Programming for Industrial Control - using ( IEC 1131-3 and OPC )
- Practical Distributed Control Systems (DCS) for Engineers & Technicians
- Practical Data Acquisition using Personal Computers and Standalone Systems
- Best Practice in Process, Electrical & Instrumentation Drawings and Documentation
- Practical Troubleshooting of Data Acquisition & SCADA Systems
- Practical Industrial Flow Measurement for Engineers and Technicians
- Practical Hazops, Trips and Alarms
- Practical Hazardous Areas for Engineers and Technicians
- A Practical Mini MBA in Instrumentation and Automation
- Practical Instrumentation for Automation and Process Control
- Practical Intrinsic Safety for Engineers and Technicians
- Practical Tuning of Industrial Control Loops
- Practical Motion Control for Engineers and Technicians
- Practical SCADA and Automation for Managers, Sales and Administration
- Practical Automation, SCADA and Communication Systems: A Primer for Managers

Power Systems Protection, Power Quality, Substation Automation
- Practical Fundamentals of OPC (OLE for Process Control)
- Practical Process Control for Engineers and Technicians
- Practical Process Control & Tuning of Industrial Control Loops
- Practical Industrial Programming using 61131-3 for PLCs
- Practical SCADA & Telemetry Systems for Industry
- Practical Shutdown & Turnaround Management for Engineers and Managers
- Practical Safety Instrumentation and Shut-down Systems for Industry
- Practical Fundamentals of E-Manufacturing, MES and Supply Chain Management
- Practical Safety Instrumentation & Emergency Shut-down Systems for Process Industries
- Control Valve Sizing, Selection and Maintenance

MECHANICAL ENGINEERING
- Practical Fundamentals of Heating, Ventilation & Airconditioning (HVAC)
- Practical Boiler Plant Operation and Management for Engineers and Technicians
- Practical Bulk Materials Handling (Conveyors, Bins, Hoppers & Feeders)
- Practical Pumps and Compressors: Control, Operation, Maintenance & Troubleshooting
- Practical Cleanroom Technology and Facilities for Engineers and Technicians
- Gas Turbines: Troubleshooting, Maintenance & Inspection
- Practical Hydraulic Systems: Operation and Troubleshooting
- Practical Lubrication Engineering for Engineers and Technicians
- Practical Safe Lifting Practice and Maintenance
- Practical Mechanical Drives (Belts, Chains etc) for Engineers & Technicians
- Fundamentals of Mechanical Engineering
- Practical Pneumatics: Operations and Troubleshooting for Engineers & Technicians
- Practical Centrifugal Pumps - Optimising Performance
- Practical Machinery and Automation Safety for Industry
- Practical Machinery Vibration Analysis and Predictive Maintenance

PROJECT & FINANCIAL MANAGEMENT
- Practical Financial Fundamentals and Project Investment Decision Making
- How to Manage Consultants
- Marketing for Engineers and Technical Personnel
- Practical Project Management for Engineers and Technicians
- Practical Specification and Technical Writing for Engineers

CHEMICAL ENGINEERING
- Practical Fundamentals of Chemical Engineering

CIVIL ENGINEERING
- Hazardous Waste Management and Pollution Prevention
- Structural Design for non-structural Engineers
- Best Practice in Sewage and Effluent Treatment Technologies
Comprehensive Training Materials

Workshop Documentation

All IDC Technologies workshops are fully documented with complete reference materials including comprehensive manuals and practical reference guides.

Software

Relevant software is supplied with most workshops. The software consists of demonstration programs which illustrate the basic theory as well as the more difficult concepts of the workshop.

Hands-On Approach to Training

IDC Technologies engineers have developed the workshops based on the practical consulting expertise that has been built up over the years in various specialist areas. The objective of training today is to gain knowledge and experience in the latest developments in technology through cost effective methods.

The investment in training made by companies and individuals is growing each year as the need to keep topical and up to date in the industry which they are operating is recognized. As a result, IDC Technologies instructors place particular emphasis on the practical, hands-on aspect of the workshops presented.

On-site Workshops

In addition to the external workshops which IDC Technologies presents on a world-wide basis, all IDC Technologies workshops are also available for on-site (in-house) presentation at our clients premises.

On-site training is a cost effective method of training for companies with many delegates to train in a particular area. Organizations can save valuable training $$$ by holding workshops on-site, where costs are significantly less. Other benefits are IDC Technologies ability to focus on particular systems and equipment so that attendees obtain only the greatest benefits from the training.

Power Systems Protection, Power Quality, Substation Automation

All on-site workshops are tailored to meet with clients training requirements and workshops can be presented at beginners, intermediate or advanced levels based on the knowledge and experience of delegates in attendance. Specific areas of interest to the client can also be covered in more detail.

Our external workshops are planned well in advance and you should contact us as early as possible if you require on-site/customized training. While we will always endeavor to meet your timetable preferences, two to three months notice is preferable in order to successfully fulfil your requirements.

Please don’t hesitate to contact us if you would like to discuss your training needs.

Customized Training

In addition to standard on-site training, IDC Technologies specializes in customized workshops to meet client training specifications. IDC Technologies has the necessary engineering and training expertise and resources to work closely with clients in preparing and presenting specialized workshops.

These workshops may comprise a combination of all IDC Technologies workshops along with additional topics and subjects that are required. The benefits to companies in using training is reflected in the increased efficiency of their operations and equipment.

Training Contracts

IDC Technologies also specializes in establishing training contracts with companies who require ongoing training for their employees. These contracts can be established over a given period of time and special fees are negotiated with clients based on their requirements. Where possible IDC Technologies will also adapt workshops to satisfy your training budget.

References from various international companies to whom IDC Technologies is contracted to provide on-going technical training are available on request.
Some of the thousands of Companies world-wide that have supported and benefited from IDC Technologies workshops are:

**Australia**
- Alcoa
- Alinta Gas
- Ampel Refineries
- Ansto
- Australian Communications Authority
- Australian Geological Society
- BHP Billiton
- BOC Gases
- Boeing Constructors Inc
- Brisbane City Council
- British Aerospace Australia
- C1 Technologies
- Civil Aviation Authority
- Comalco Aluminium
- CSIRO
- Delta Electricity
- Dept of Defence
- Dept of Transport and Works
- DSTO
- Duke Energy International
- Emerson Process Management
- Energex
- ERG Group
- Ergon Energy
- ETSA
- Gippsland Water
- Gladstone Tafe College
- Gosford City Council
- Great Southern Energy
- Harnersley Iron
- Hewlett-Packard
- Holden Ltd
- Honeywell
- I&I Systems Pby Ltd
- Integral Energy
- Metro Brick
- Millennium Chemicals
- Mt Isa Mines
- Murdoch University
- Nabalco
- NEC
- Nilsson Electric
- Normandy Gold
- Nu-Lec Industries
- Parker Hannifin
- Pharmacie & Ugoibo
- Power & Water Authority NT
- Powercord
- Powerlink
- Prospect Electricity
- Queensland Alumina
- Raaf
- Raytheon
- RGC Mineral Sands
- Robe River Iron Associates
- Royal Darwin Hospital
- Santos Ltd
- Schneider Electric
- Shell
- Snowy Mountain Hydro
- SPC Fruit
- Starnall Power Station
- Telstra
- Tivest
- Uncle Bens
- Vision
- Wesfarmers CSBP
- Western Power
- Westrail
- WMC
- Woodside
- Worsley Alumina
- Wyong Shire
- Yokogawa Australia

**Botswana**
- De Beers - Jwaneng Mine
- De Beers - Orapa Mine

**Canada**
- Aircom Industries (76) Ltd
- Alico Electric
- BC Gas
- BC Hydro
- City of Ottawa
- City of Saskatchewan
- Conoco
- Dept of National Defence
- Enbridge Pipelines
- Emerex
- Ford Electronics
- GE Energy Services
- General Motors
- Guillemin Automations
- Husky Oil
- Imperial Oil
- INCO Ltd
- Labrador Hydro
- Manitoba Hydro
- Manitoba
- Lottery Corp
- Memorial University of Newfoundland
- New Brunswick Power
- Nova Chemicals
- Norgate Corporation
- Ontario Hydro
- Ottawa Hydro
- Petro Canada
- Power Measurement Ltd
- Saskatchewan Power
- Spartan Controls
- Stora
- Suncor Energy
- Syncrude
- Telus
- Trans Canada Pipelines
- Trojan Technologies
- Wascana Energy
- Weyerhaeuser

**Ireland**
- Bayer Diagnostics
- ESB Distribution
- Intel
- Irish Cement
- Janssen Pharmaceuticals
- Microset Limited
- Pfizer
- Filz Ireland
- Procon Engineering

**Nambia**
- Namibian Broadcasting Corporation
- Nampower
- Namwater

**New Zealand**
- ACI Packaging
- Anchor Products
- Auckland Regional Council
- Ballance Agri

**United Kingdom**
- 24 Seven
- ABB Automation Ltd
- Aer Rianta
- Air Products
- Allied Colloids
- Allied Distillers
- Alstom
- BAE Systems
- Bechtel
- BNFL
- Magnus Generation
- BP Chemicals
- British American Tobacco
- British Energy
- British Gas
- British Steel
- Cegelec
- Conoco
- Corsus Group Plc
- Energy Logistics
- Eurothorâm
- Eurotunnel
- Evesham Microsystems
- Exxt Ltd
- Fisher Rosemount
- GEC Meters
- Glaxo Smith Kline
- Glaxo Wellcome
- Great Yarmouth Power
- Halliburton
- Honeywell
- ICI
- Nobel Enterprises
- ICS Triplex
- Innmarsat Ltd
- Istemi Limited
- Johnson Matthey
- Kodak
- Kvaerner Energy
- Lever Fabric
- Lindsay Oil Refinery
- Lloyds
- Logica
- Lucas Aerospace
- Mobil Oil
- NEC
- Nissan
- Northern Lighthouse Board
- OKJ Europe Ltd
- Phillips Petroleum
- Powergen
- Qinetiq
- Rail Track Systems
- Rig Tech
- Robert's & Partners
- Rolls Royce
- Rover Group
- Rugby Cement
- Scottish Courage
- Scottish Hydro Electric Plc
- Scottish Power
- Shell Chemicals
- Shotton Paper Plc
- Siemens
- Strathclyde Water
- Thames Water
- Toyota
- Transco
- Trend Control Systems Ltd
- UKAEA
- United Kingdom Paper
- Yarrow Shipbuilders
- Yorkshire Electric

**USA**
- Alcatel
- Allen Bradley
- Astra Zeneca Pharmaceuticals
- Arista Corporation
- Boeing
- Chevron
- City of Detroit
- Dashiyani Paper Mill
- Degussa Corporation
- Delta Energy
- Detroit Water
- Exxon Mobil Chemical Company
- FMC Corporation
- General Motors
- Honeywell
- Hughes Aircraft
- ISA
- K-Tron Institute
- Mckee Foods
- Milltronics
- NASA
- Pappel Fuchs
- Phelps Dodge
- Philip Morris
- San Diego County Water Authority
- San Francisco Water Department
- Santa Clara Valley Water
- Security Industry Automation Corp
- Siemens Power
- Siemens Westinghouse
- Toyota
- Tucson Electric
- United Technologies Corp
- Valtek
- Washington Water Power
- Wisconsin Power
- Zeneca

- The IDC Engineers Pocket Guide

- Power Systems Protection, Power Quality, Substation Automation

- Nutrients
- Contact Energy
- Ericsson
- Fisher & Paykel
- GEC Alsthom
- James Hardie
- Methane
- Natural Gas
- NZ Water and Waste Assoc
- Norske Skog
- NZ Alumina
- Smelters
- NZ Refining Co
- Pan Pac Forest Products
- Powerco
- Rockwell
- Rotorua District Council
- Royal New Zealand Navy
- The University of Auckland

- Activemedia Innovation Pte Ltd
- Flotech Controls
- Land Transport Authority
- Ngee Ann Polytechnic
- Power Seraya Ltd
- Westinghouse
- Yokogawa Singapore
IDC Technologies - Worldwide Offices

For further information about current or future workshops please contact your local office:

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