Contents

1 unfiled lol make sure everything makes sense tho

1.1 Impedance Matching

Definition

Impedance: the total resistance of a given electric component or AC circuit originating from reactive and resistance of the given system. Has both *phase* and *resistance* for AC. For DC, impedance has zero phase angle.
Impedance matching: the process where the input impedance and the output impedance of a given electrical load are designed to reduce signal reflection and maximize the power transferred to the electric load.

1.1.1 Motivation

Impedance matching has great use in high-frequency and high-speed devices.

When designing applications of ultra-high frequencies, impedance matching becomes a difficult operation for designers. The challenge is also reflected while designing microwaves and radio frequency circuits. When you get a wrong impedance matching, expect distorted pulses and high signal reflections.

An increase in frequency decreases the window of errors. The electrical circuit works the best when we have a perfectly matched impedance. If the impedance matching is not done, expect the system to work abnormally because of the effects such as the signal reflections. The reflected waves cause data delays and distortion of the phase and minimize the ratio of signal to noise.

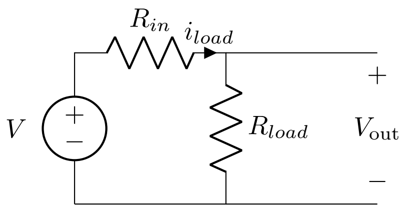
Concept

Maximum power transfer occurs when the resistance of the voltage source is equal to the resistance of the load.

We can show this by taking the derivative of the power function. At maximum power transfer, this derivative is equal to zero

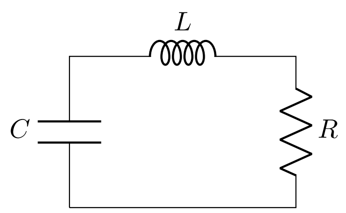
1.1.2 Examples

1. Suppose that we have a system that is modeled by the circuit below



$$P = I_{load}^2 R_{load} = \frac{V^2 R_{load}}{(R_{in} + R_{load})^2}$$
$$\frac{dP}{dR_{load}} = \frac{V^2(R_{in} + R_{load})^2 - 2R_{load}(R_{in} + R_{load})V^2}{(R_{in} + R_{load})^4} = 0 \Rightarrow R_{load} = R_{in}$$

2. Suppose now you have the following circuit



The admittance of the circuit, Y_{in} is the inverse of the impedance. Here are the general steps for finding some R' and R such that their impedances matched

(a) Calculate the impedance Z of the circuit.

(b) Set admittance $Y = \frac{1}{Z}$.

(c) Separate your admittance into its real and imaginary part to take the real part of Y.

(d) $R' = \Re\{Y\}$, so that R' here is a function of R.

i dont feel like doing the calculations right now im too tired do later though : link

3. **Transformer impedance matching:** set the turn ratio accordingly. Low voltage → fewer turns.

Definition

$$\text{Turns ratio} = \sqrt{\frac{\text{Source resistance}}{\text{Load resistance}}}$$

4. **Transmission line:** Transmission of electrical energy from the source to the load is done using a transmission line. While transferring this energy, it is important to zero or minimize energy losses that occur. For this to be possible, we should match the source and load impedances to the transmission line being used.

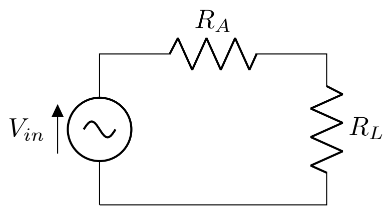
The characteristic impedance is defined as the voltage and current wave ratio at any given point along the transmission line. If the transmission line in discussion is long, then we expect to have a different characteristic impedance at different distances along this transmission line. If we fail to do the impedance matching, the signs reaching the load will be reflected in the source of the origin, giving rise to a standing wave. The amount of power reflected is measured using the coefficient of reflection, which is calculated using the equation below

Definition

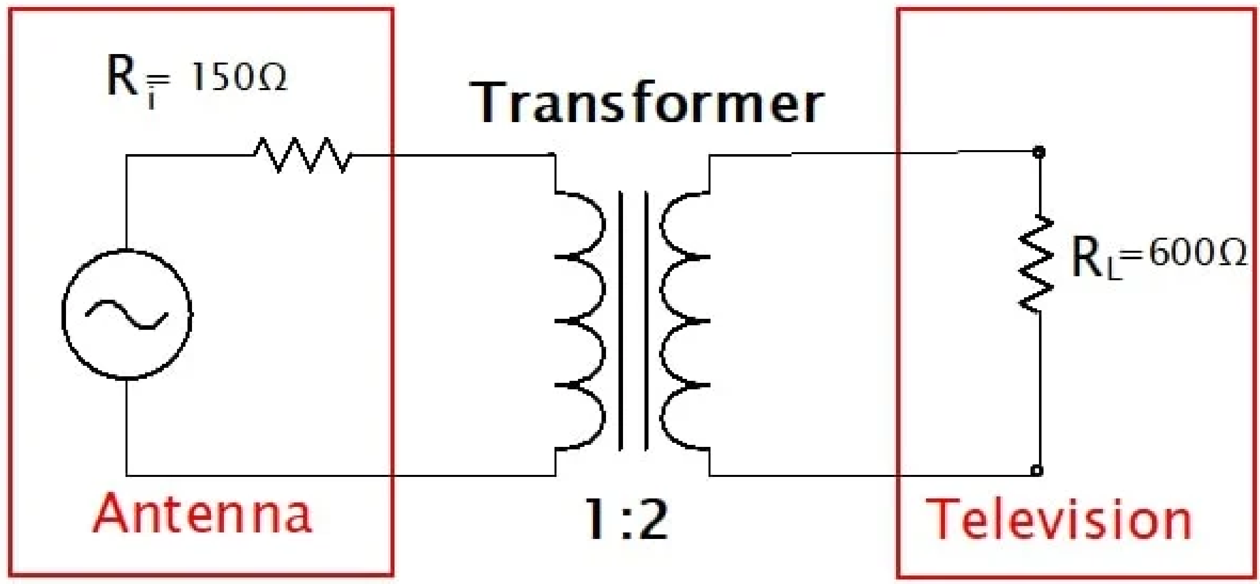
$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

Z_L: line impedance, Z_0: characteristic impedance

5. Attenna and television



R_A is the resistance of the antenna is 150Ω and its cable while the TV's resistance is 600Ω. Use the turns ratio formula to find the number of turns. Then set a transformer in between like in the image below.



6. In the case of the headphone, the signal source is the device where the headphone is plugged. The headphone is the load. For the system to attain quality audio output, the source, and the load impedances must be matched. By matching the impedances, we make sure that there is maximum power transfer from the source of the audio to the headphone.

   When building portable devices, ensure that low-impedance headphones are built. This makes the system work well with proper sound quality.

2 Introduction to Power

What is Power Electronics?

Definition

Source: something that generates power
Load: something that consumes power
Power electronics: application of electronics and circuitry to control the conversion of one form to another

Converter types between AC and DC Power: DC stands for "direct current" and can be visualized as a constant voltage over time. One example is a battery and photovoltaic panel. AC power stands for "alternating current" and is a sinusoidal voltage in time. An example of this is the power from the outlet. There are four basic types of converters.

- AC-DC: AC source to DC load, which is commonly called a rectifier like in the use of a laptop charger
- DC-DC: DC source to DC load, battery pack USB
- DC-AC: DC source to AC load, also commonly called an inverter like for a photovoltaic to grid system
- AC-AC: AC source to AC load, not as common but used in wond power system

2.1 Average and Root Mean Square (RMS) Calculations

Period waveforms repeat their shape across each period. The average value of a sine wave is 0. $\langle v(t)\rangle = \frac{1}{T}\int_0^T v(t)\,dt$ will represent the average value here.

The RMS is represented as capital V listed below

Definition

$$V = \sqrt{\frac{1}{T}\int_0^T v(t)^2\,dt}$$

We can think of the RMS value as the equivalent voltage if we put the waveform of choice across a resistor

The power is equal to the voltage waveform squared over the resistor. The triangle brackets represent the average here.

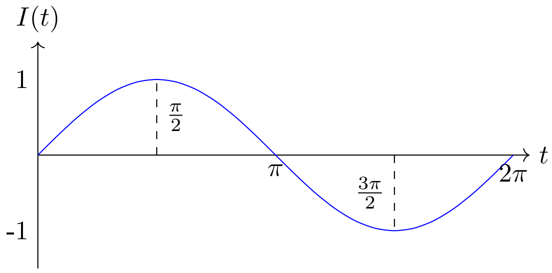
Definition

$$\langle P \rangle = \langle \frac{v^2}{R} \rangle = v^2$$

Remember that

$$\langle v \rangle^2 \neq v^2$$

If we take a look at this sine wave and say that this represents current and connected this to a resistor, average power would not be 0 even though average current is 0. $I(t)$ here represents the instantaneous value. The resistor generates (consumes) power at both the negative and positive parts of this waveform.



Sanity Check

Is the RMS value always greater than or equal to the average value? Yes. Recall the definitions of average value and the RMS value above. My intuition behind this is that you're squaring a periodic function there will be no negative values.

Sine wave RMS value calculations:

Define $x(t) = X_{peak}\sin(t \times \frac{2\pi}{T})$. We multiply t by a factor of $\frac{2\pi}{T}$ since we are working in units of time.

$$\begin{aligned}
X_{RMS} &= \sqrt{\frac{1}{T}\int_0^T X_{peak}^2 \sin^2(t \times \frac{2\pi}{T})\,dt} && (1)\\
&= \sqrt{\frac{X_{peak}^2}{T}\int_0^T (1-\cos(2\cdot\frac{2\pi}{T}))\,dt} && (2)\\
&= \sqrt{\frac{X_{peak}^2}{2T}\left[t\,|_0^T - \sin(\frac{4\pi t}{T})\frac{T}{4\pi}\,|_0^T\right]_0^T} && (3)\\
&= \sqrt{\frac{X_{peak}^2}{2T}\left[T - \frac{T}{4\pi}(\sin(4\pi) - \sin(0))\right]_0^T} && (4)\\
&= \frac{X_{peak}}{\sqrt{2}} && (5)
\end{aligned}$$

Line (2) comes from the trig idenity

$$\sin^2 u = \frac{1-\cos(2u)}{2}$$

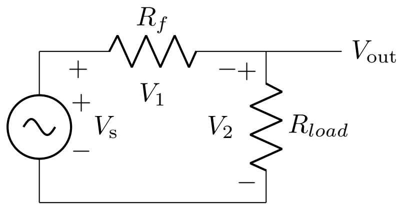
Line (3) comes from evaluating the integral. In line (4), we see that everything within the brackets evaluates to T and that this results in T cancelling out with the T in the denominator, resulting in just a 2 in the denominator, which is later square rooted.

2.1.1 X_{peak} and Oscilloscope Readings

We notice that X_{peak} is described in its RMS value as the large value that we can get. The amplitude of this sine wave is 1, but if we were to output this sinusoid in High-Z mode on the function generator, we would have to set this to a 2 V_{pp} (Volt peak to peak). Contrastingly, if we were in 50-Ohm mode, setting the function generator to 2 V_{pp} would result in a sinusoid with an X_{peak} of 4 V.

Why is my function generator's output voltage wrong?

1. **Scope vertical scale is using wrong probe attenuation.** A lot of scopes set this vertical scale automatically for you, so you may have to set this scale to be larger or smaller depending on how large your voltage is.
2. **Load impedance is different from what the generator expects.** Image a voltage divider below. If our function generator wants to output 1 V_{pp} at R_{load} then, if $R_f = 50\Omega$ and it assumes the R_{load} is also 50Ω then that means thats the function generation will set V_s as $2V_{pp}$. However, sometimes it is the case that if R_{load} is too high (such as in the case of the oscilloscope itself) then that means that voltage drop across R_f is not that big and most of the voltage drop occurs across R_f. This results in us reading 2 V_{pp} when we meant to output 1 V_{pp}. To correct this, correct the load impedance on the function generator settings if you have the setting for it to High-Z or what your load impedance on whatever you're connecting to is or connect a 50 Ω through terminator to your coax on your lead.



2.2 Real, Reactive and Apparent Power

There are three different types of AC power. ϕ here is the impedance phase angle between the voltage and the current.

Definition

Apparent power: product of the RMS current and RMS voltage and represented by S in units of VA

$$S = V_{RMS} I_{RMS}$$

Active/Real power: power consumed or used within an AC circuit and represented by P. Is the real power in units of W (watts)

$$P = V_{RMS} I_{RMS} \cos\phi$$

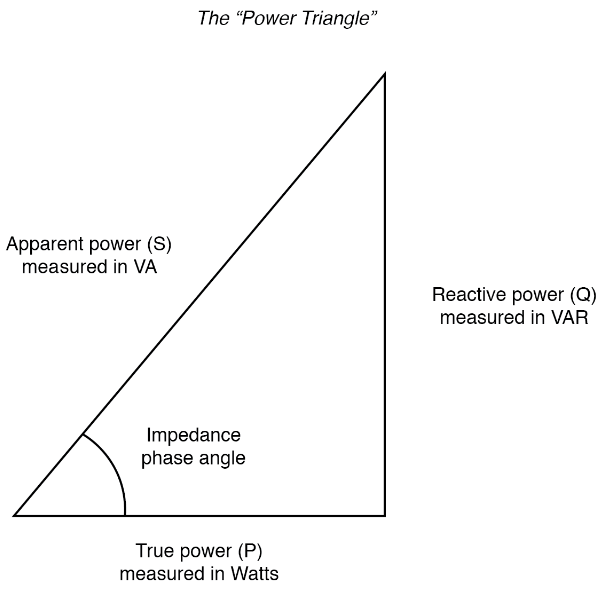
Reactive power: the power developed in the circuit and represented by Q in units of VAR. Is the maximum value of the power component that "messes around", going back and forth

$$Q = V_{RMS} I_{RMS} \sin\phi$$

We can describe the differences between apparent, reactive, and real power with a "sending a package analogy". The item you want to ship is your real power. To deliver power, you need a container, which is your apparent power. This has the potential to send an amount of power. However, you need some packaging in the container to cushion your item, which is your reactive power.

- Real - item. Reactive loads like inductors and capacitors dissipate zero power
- Reactive - packaging. The actual amount of power being used or dissipated
- Apparent - box. This is the combination of reactive and real power and is without reference to phase angle.

2.2.1 Pure Load Examples



2.3 Power Factor

3 Power Converters

Our switching converter is made

4 Tranmission and Distribution

4.1 Three-phase Electric Power

Definition

Three-phase electric power: a common type of alternating current (AC) used in electricity generation, transmission, and distribution. Typically employs 3-4 wires (fourth wire is an optional neutral return wire).
Line voltage: the voltage between any two lines
Phase voltage: the voltage measured between any line and neutral

This three-phase electric power is a common method used by electrical grids to transfer power. The voltage on each wire is 120° phase shifted from each other. This allows voltages to be stepped up using transformers to high voltage and stepped down for distribution. Each conductor in a *symmetric* three-phase power supply system carries an alternating current of the same frequency and voltage amplitude. You can design assymetric three-phase power systems, but are not used in practice.

Convention states that for a 208/120-volt service, that means that the line voltage is 208 volts and the phase voltage is 120 volts.

4.1.1 Advantages

If we had to compare a three-phase supply to a single phase AC power supply (with two current-carrying conductors, phase and neutral), a three-phase supply with no neutral and the same phase-to-ground voltage/current capacity per phase would transmit 3 times as much power with only 1.5 imes as much wires (3 vs 2 wires). This means that we get higher efficiency, lower weight, and cleaner waveforms.

Here are more properties of three-phase supplies that are desirable in electric power systems:

- Phase currents tend to cancel each other out, summing to 0 in a linear balanced load. Due to this, sometimes we don't even need a neutral conductor since it will carry little or no current.

- Power transfer into a linear balanced load is constant, which helps to reduce vibrations in motor/generators
- Can produce a rotating magnetic field with a specificed direction and constant magnitude. This simplifies the design of electric motors since no starting circuit is required

4.1.2 Disadvantages or Cautions

Make sure that the phases are connected in the correct order to achieve the intended direction of rotation of three-phase motors. If two sources are connected at the same time, then a direct connection between two different phases is a short circuit and leads to flow of unbalanced current.

4.1.3 Why not a higher number of phases?

Three phases is the minumum number that we can have without having "dead" spots in the cycle.

Industry uses almost exclusively three phase power since an induction motor needs at least a three phase supply to start and run in a known direction. Single phase induction motors require lossy, unreliable, and expensive tricks to do the same (extra windings, lossy windings, speed sensitive switch, capacitors, etc).

The supply grid is based on three phase since that is the most efficient in terms of generation and delivery. Using a 9 phase grid for example would require running 9 wires for the entire distribution grid, not cost effective.

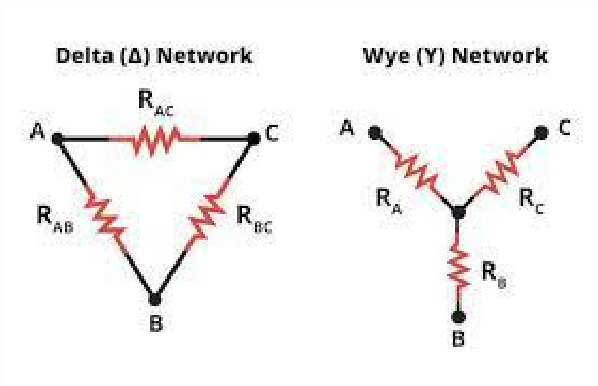
The higher order motors mentioned don't use line generated phases. Stepper motors use more phases for finer control. High order polyphase rectifiers are designed often with more 'phases', to reduce ripple, but the phases are generated locally by phase-shifting the line input by some means, either direct LC shifting, or by using a motor-generator set.

Mathematically there is no improvement in motor smoothness, 3 is already an optimal case.

4.1.4 Delta and Wye

There are two basic three-phase configurations

Definition



For a ⅄ configuration, there is an optional fourth wire, which serves as a neutral and is normally grounded. The ground wire present above many transmission lines are for fault protection and doesn't carry current under normal use.

There are four different types of three-phase transformer winding connections for transmission and distribution.

1. ⅄ – ⅄: for small current and high voltage
2. $\Delta - \Delta$: for large currents and low voltages
3. Δ – ⅄: for step-up transformers (ie generating stations)
4. ⅄ – Δ: for step-down transformers (ie at end of the transmission)

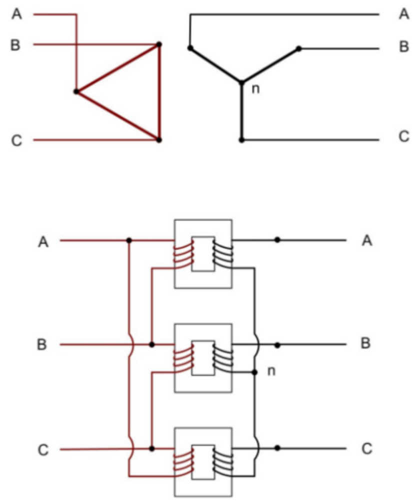


Figure 1: This shows a delta-wye configuration across a transformer core. A practice transformer wouldn't have a different number of turns on each side.

4.2 Single-Line Diagrams (SLD)

Definition

Single-line diagram: representation of an electrical system, providing a view of its components, interconnections, and electrical flow paths
Bus: in an electrical system, this is a node where several line or several lines are connected. In power systems specifically, this is any garph node of the single-line diagram at which voltage, curernt, power flow or other quantities can be evaluated

More detailed explanation from Schematic Representation of Power System Relaying report:

Shows the overall scheme and connections and interactions between equipment and relay system components but in a simplified manner. For example, it uses a single line to represent three phases (hence the name "single line"). The information is shown schematically, but the high- voltage portion is usually shown in a pseudo-physical layout that matches or mimics the actual bus layout in the substation. All relays and other major components are assigned a unique identification. The identification is carried through the entire drawing set. There may be other drawings in the single line format. There may also be a one line diagram that emphasizes the power system equipment and does not detail the relay system components but only those elements connected directly at the primary voltage. This may be referred to as the "station", "station one line", or "power one line" diagram. There may also be a simplified one line diagram showing all the protection schemes and their intended zones of protection. This is referred to as the "protection zone" or "meter and relay single line" diagram.

Components on a single-line diagram

- Power sources - includes generators, utility supplies and indicates their voltage levels and connection points to the electrical system
- Electrical Equipment - includes transformers, circuit breakers, switches, motors, and loads
- Bus arrangement - includes bus bars for power distribution at different voltage levels and shows how power is routed from one location to another
- Protective devices - includes fuses, circuit breakers, and relays
- Metering/instrumentation - includes metering devices (ammeter, voltmeter etc) and measuring points for monitoring/control

Bus Arrangement and Voltage Levels

Definition

Bus duct
- Carries high currents between different electrical components and sections
- Ensures efficient power distribution and reduce

Transformer
- Used to step down or setp up voltage levels
- Placed at locations to convert high-voltage power from the utility grid to lower voltages or to increase voltage for long-distance Transmission
- Winding figurations, type, kVA ratings, cool methods, and surge/lightning protection devices are listed

Voltage/current transformers (VT, CT)
- Used to measure voltage and current levels for metering, protection, and control purposes

Single line diagrams are the most simplified schematic and least detailed since they rely on basic symbols. We can list a drawing hierarchy from least to most detailed.

1. Single line
2. AC/DC schematics
3. Logic/wiring diagrams

Each type of schematic has different meaning depending on the intended use. Day to day activities associated with power system work include planning, designing, managing, estimating, commissioning, testing, operating, maintaining, consulting, and providing legal records. The activities are performed by personnel from different organizational groups such as attorneys, project managers, electricians, relay technicians, design engineers, substation operators, system dispatchers, and system planners. How each function is situated within the organizational structure of a power system operator might impact how the different types of drawings are combined and used. Certain functions such as real time power system operation have very high priority when compared to activities such as accounting that can be done at any time after the fact. This is then reflected into the level of detail contained by each type of drawing depending upon its purposes and priorities.

4.2.1 Symbols

It is difficult to keep a SLD easy to read while including all the necessary data. We want to communicate function using symbols

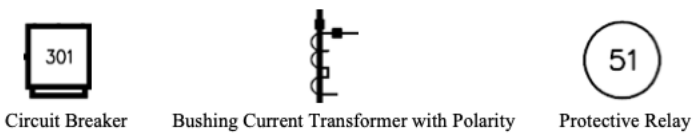


Figure 2: Examples of symbols used on one line diagrams

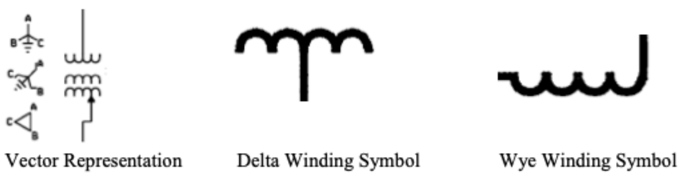


Figure 3: Three phase connection in a SLD

More symbols loaded below

Standard Elementary Diagram Symbols

The diagram symbols in Table 1 are used by Square D and, where applicable, conform to NEMA (National Electrical Manufacturers Association) standards.

Table 1 Standard Elementary Diagram Symbols

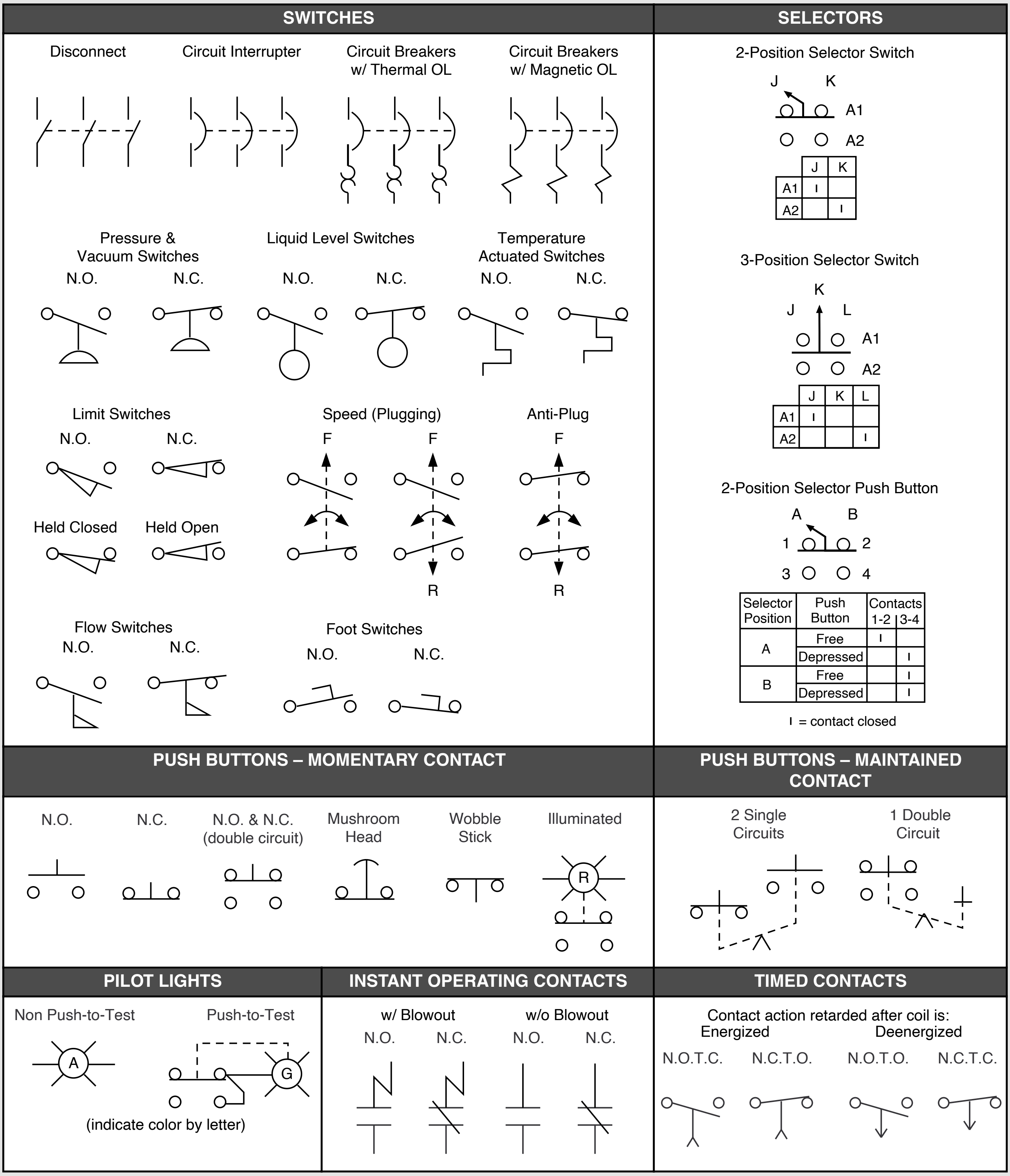


Table 1 Standard Elementary Diagram Symbols (cont'd)

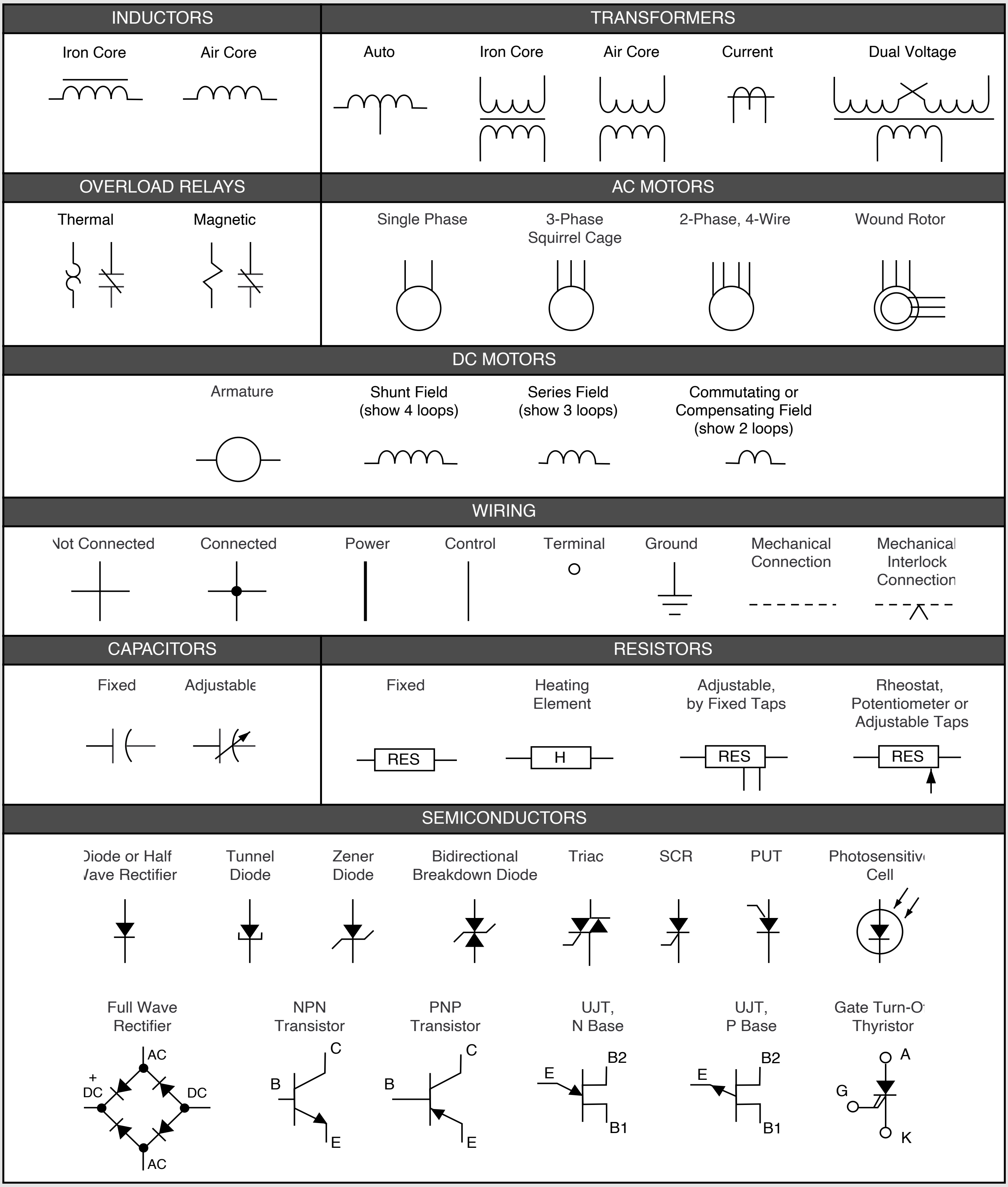
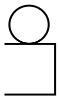


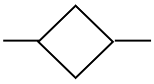
Table 1 Standard Elementary Diagram Symbols (cont'd)

OTHER COMPONENTS

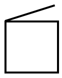
Bell



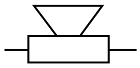
Annunciator



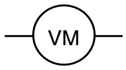
Buzzer



Horn, Alarm, Siren,etc.

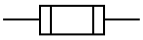


Meter (indicate type by letters)

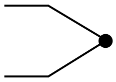


Battery

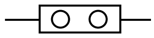
Fuse



Thermocouple



Meter Shunt

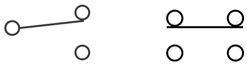


SUPPLEMENTARY CONTACT SYMBOLS

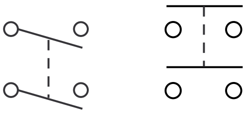
SPST, N.O.
Single Break Double Break

SPST, N.C.
Single Break Double Break

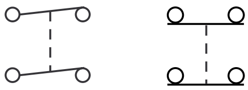
SPDT
Single Break Double Break



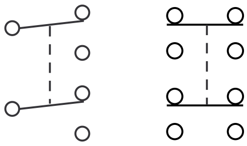
DPST, 2 N.O.
Single Break Double Break



DPST, 2 N.C.
Single Break Double Break

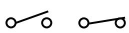


DPDT
Single Break Double Break

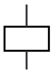


IEC SYMBOLS

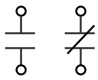
Push Buttons
N.O. N.C.



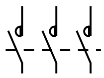
Coil



Aux. Contacts
N.O. N.C.

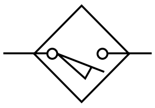


Contactor Breakers



STATIC SWITCHING CONTROL

Limit Switch, N.O., Static Control



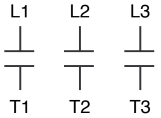
Static switching control is a method of switching electrical circuits without the use of contacts, primarily by solid state devices. To indicate static switching control, use the symbols shown in this table, enclosing them in a diamond as shown.

TERMS

SPST:	Single Pole, Single Throw	N.O.:	Normally Open	PUT:	Programmable Unijunction Transistor
SPDT:	Single Pole, Double Throw	N.C.:	Normally Closed	SCR:	Silicon Controlled Rectifier
DPST:	Double Pole, Single Throw	T.O.:	Timed Open	Triac:	Bidirectional Triode Thyristor
DPDT:	Double Pole, Double Throw	T.C.:	Timed Closed	UJT:	Unijunction Transistor

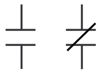
Table 2 NEMA and IEC Terminal Markings

NEMA



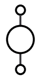
Alphanumeric, corresponding to incoming line and motor terminal designations

Power Terminals



No specific marking

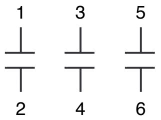
Control Terminals



No standard designation

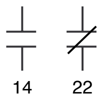
Coil Terminals

IEC



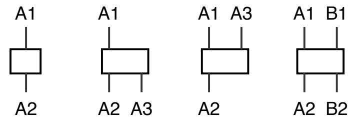
Single digit numeric, odd for supply lines, even for load connections

Power Terminals



2-digit numeric, 1st designates sequence, 2nd designates function (1-2 for N.C., 3-4 for N.O.)

Control Terminals

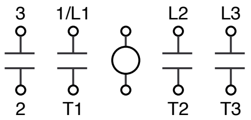


One Winding | Tapped Winding | Tapped Winding | Two Windings

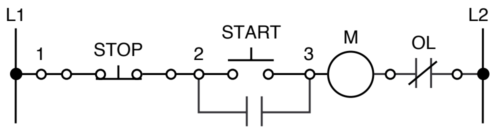
Coil Terminals

Table 3 NEMA and IEC Controller Markings and Elementary Diagrams

NEMA

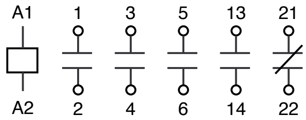


Typical Controller Markings

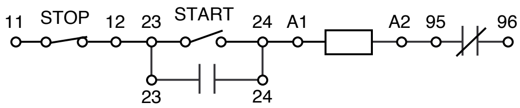


Typical Elementary Diagram

IEC



Typical Controller Markings



Typical Elementary Diagram

Table 4 Control and Power Connections for Across-the-Line Starters, 600 V or less
(From NEMA standard ICS 2-321A.60)

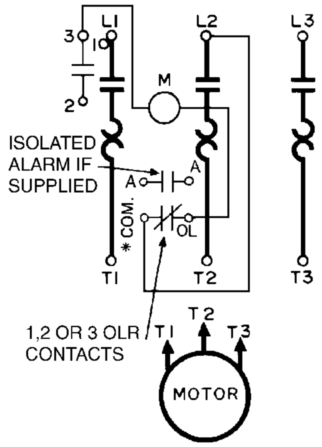
		1-Phase	2-Phase, 4-Wire	3-Phase
Line Markings		L1, L2	L1, L3: Phase 1 L2, L4: Phase 2	L1, L2, L3
Ground, when used		L1 is always ungrounded	—	L2
Motor Running Overcurrent, units in:	1 element	L1	—	—
	2 element	—	L1, L4	—
	3 element	—	—	L1, L2, L3
Control Circuit Connected to		L1, L2	L1, L3	L1, L2
For Reversing, Interchange Lines		—	L1, L3	L1, L3

WIRING DIAGRAM

A wiring diagram shows, as closely as possible, the actual location of all component parts of the device. The open terminals (marked by an open circle) and arrows represent connections made by the user.

Since wiring connections and terminal markings are shown, this type of diagram is helpful when wiring the device or tracing wires when troubleshooting. Bold lines denote the power circuit and thin lines are used to show the control circuit. Black wires are conventionally used in power circuits and red wire in control circuits for AC magnetic equipment.

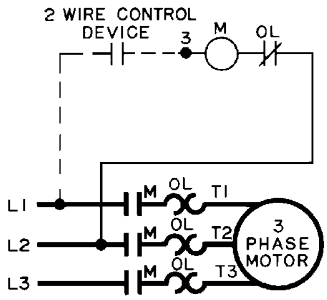
A wiring diagram is limited in its ability to completely convey the controller's sequence of operation. The elementary diagram is used where an illustration of the circuit in its simplest form is desired.



ELEMENTARY DIAGRAM

An elementary diagram is a simplified circuit illustration. Devices and components are not shown in their actual positions. All control circuit components are shown as directly as possible, between a pair of vertical lines representing the control power supply. Components are arranged to show the sequence of operation of the devices and how the device operates. The effect of operating various auxiliary contacts and control devices can be readily seen. This helps in troubleshooting, particularly with the more complex controllers.

This form of electrical diagram is sometimes referred to as a "schematic" or "line" diagram.



Examples of Control Circuits

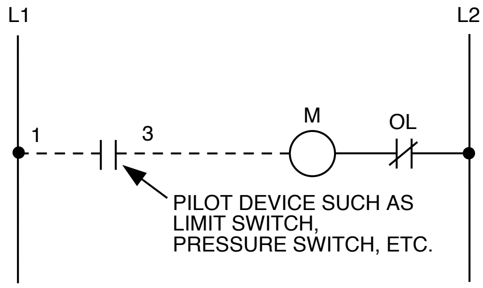
2- and 3-Wire Control
Elementary Diagrams

Low Voltage Release and Low Voltage Protection are the basic control circuits encountered in motor control applications. The simplest schemes are shown below. Other variations shown in this section may appear more complicated, but can always be resolved into these two basic schemes.

Note: The control circuits shown in this section may not include overcurrent protective devices required by applicable electrical codes. See page 11 for examples of control circuit overcurrent protective devices and their use.

Low Voltage Release: 2-Wire Control

FIG. 1



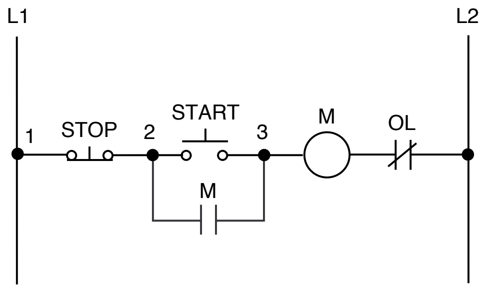
Low voltage release is a 2-wire control scheme using a maintained contact pilot device in series with the starter coil.

This scheme is used when a starter is required to function automatically without the attention of an operator. If a power failure occurs while the contacts of the pilot device are closed, the starter will drop out. When power is restored, the starter will automatically pickup through the closed contacts of the pilot device.

The term “2-wire” control is derived from the fact that in the basic circuit, only two wires are required to connect the pilot device to the starter.

Low Voltage Protection: 3-Wire Control

FIG. 2



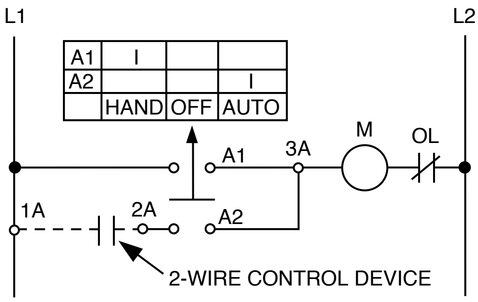
Low voltage protection is a 3-wire control scheme using momentary contact push buttons or similar pilot devices to energize the starter coil.

This scheme is designed to prevent the unexpected starting of motors, which could result in injury to machine operators or damage to the driven machinery. The starter is energized by pressing the Start button. An auxiliary holding circuit contact on the starter forms a parallel circuit around the Start button contacts, holding the starter in after the button is released. If a power failure occurs, the starter will drop out and will open the holding circuit contact. When power is restored, the Start button **must** be operated again before the motor will restart.

The term “3-wire” control is derived from the fact that in the basic circuit, at least three wires are required to connect the pilot devices to the starter.

2-Wire Control: Maintained Contact Hand-OFF-Auto Selector Switch

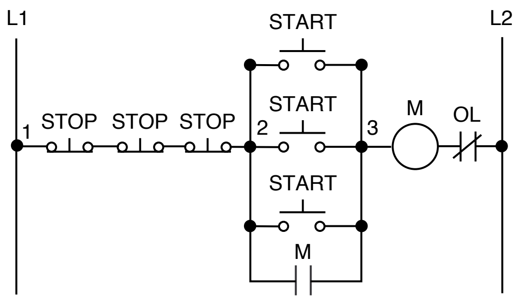
FIG. 3



A Hand-Off-Auto selector switch is used on 2-wire control applications where it is desirable to operate the starter manually as well as automatically. The starter coil is manually energized when the switch is turned to the Hand position and is automatically energized by the pilot device when the switch is in the Auto position.

3-Wire Control: Momentary Contact Multiple Push Button Station

FIG. 4



When a motor must be started and stopped from more than one location, any number of Start and Stop push buttons may be wired together. It is also possible to use only one Start-Stop station and have several Stop buttons at different locations to serve as an emergency stop.

4.3 How to read AC & DC Schematics and Power System Relaying

Concept

At its core, schematics graphically arrange the components of a system to emphasize the functional arrangement as opposed to the physical arrangement. Emphasizing function facilitates an understanding of how the system is supposed to operate and makes functional testing of systems much easier because it highlights relationships between elements.

Other names for AC schematics include, AC Elementary Diagrams or Three Line Diagrams. DC Schematics are referred to as elementary wiring diagrams. The DC schematics depict the DC system and shows the protection and control functions of the equipment in the substation. Sometimes the control functions are supplied by AC and are included in the elementary diagram. Standards in the AC and DC schematic can differ slightly from utility to utility. Both of these schematics will include the rating for circuit elements like resistors, transformers etc.

Any depiction of reality by the single line diagram is on a large scale, it might show where major pieces of equipment are in relation to each other. On the other hand, though the AC and DC schematics still don't show reality in every detail, they will contain information that will provide the link between the real depiction of the equipment seen in wiring diagrams and the almost purely functional depiction shown in the single line diagram.

Another vital function of the AC schematic is to show how the AC current and voltage circuits can be isolated for testing. For example, microprocessor delays might contribute to how secondary input quantities are measured as well as the directional sensitivity of specific elements.

Concept

AC and DC schematics allow users to quickly trace a signal through the circuit and understand the function without regard to the actual physical wiring locations. Detail will include specific terminal numbers of devices and test switches to which connections are made.

4.3.1 Common Practices

1. If complexity of the system requires it, the devices controlling the equipment.
2. The DC circuit is usually shown with the positive bus closer to the top of the page and the negative bus closer to the bottom. The general layout of these drawings is that the DC source is usually shown at the left end of the drawing and the initiating contacts are shown above the operating elements. Control flow is generally shown so that the diagram is read from upper left to lower right.

4.3.2 DC Schematics and IEC 61850 Station Bus

DC schematics: relay systems almost universally use DC for the controls; control ladder diagram or sometimes these are also referred to as elementary wiring diagrams.

IEC 61850 differs from other standards/protocols because it comprises several standards describing client/server and perr-to-peer communications, substation design and configuration, and testing. IEC 61850 provides a method for relay-to-relay interoperability between IEDs from different manufacturers. With the open architecture, it freely supports allocation of C37.2 device functions. The station bus described by IEC 61850 operates digitally over a secure Ethernet based network sending protecting relay messages called Generic Substation Events (GSE) or Generic Object Oriented Substation Events (GOOSE) between relays and other intelligent electronic devices (IEDs) on that network.

Because of this feature, it eliminates most dedicated control wiring that would normally be wired from relay-to-relay (i.e. a trip output contact from one relay to the input coil of another relay). Due to this digital communication between relays, a typical DC schematic diagram alone is not an adequate method for describing the system.

4.4 High Voltage Direct Current

Faults are defined as defects in the power system from current being distracted from the intended path.

4.5 SCADA

SCADA stands for supervisory control and data acquisition. A SCADA system is a software-based application utilized within industrial manufacturing that controls an array of hardware components. Furthermore, as the acronym suggests, a SCADA system would contain a data component that would provide a historical overview of a system to the user. Such systems are employed within manufacturing environments in order to consolidate controls over multiple production lines, collect actionable data and to drive business decisions leading to process control and improvement.

The main goals of a SCADA system are listed:

1. Control of manufacturing equipment on the plant floor
2. Control and view of plant floor devices: Programmable Logic Controllers, sensors, valves, variable frequency drives, temperature probes, etc
3. Display of real-time critical process information
4. Acquisition, storage, and display of historical data

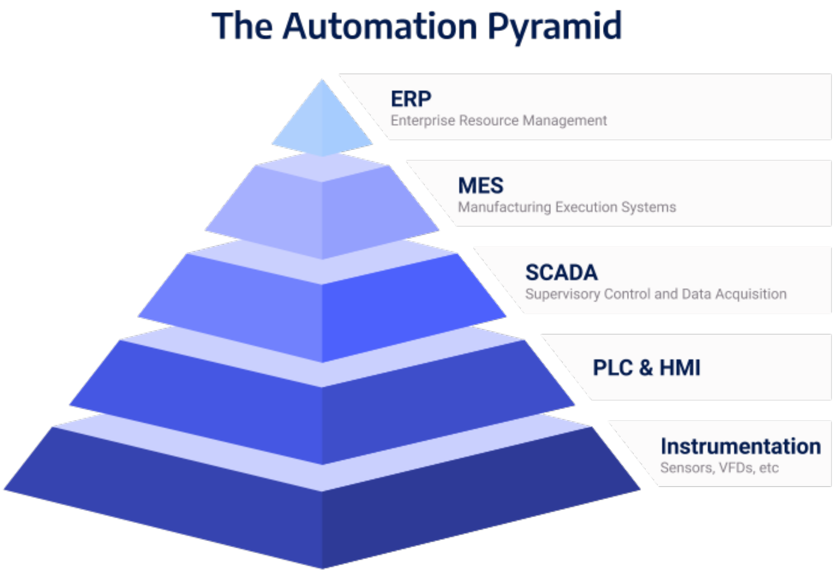


Figure 4: Automation pyramid to highlight how SCADA fits on here

A SCADA system would need to receive information from the PLC & HMI to communicate with the instrumentation layer. Here PLC stands for programmable logic controller and HMI stands for human machine interface. The HIM system would display the current status of the system, alarms associated with the asset as well as a control screen used to make adjustments. An HMI would send the information to the PLC and vice versa; it would not interact with the instrumentation directly.

Control systems engineers to create a communication layer that would be instantiated within every PLC in order to pass data accordingly. An important infrastructure within this layer is the network. Although the PLC and HMI layers will require a network for data, the SCADA system would create an additional strain on the plant network due to the volume of data it will consume.

> **Concept**
>
> SCADA refers to software while a PLC will refer to hardware. PLC as the brain of the production floor while SCADA connects to the PLC and processes this information.

4.5.1 Popular SCADA Software

Different approaches to different components for each system results in each one being better suited for certain applications

Here are the following softwares mentioned:

Rockwell Automation - FactoryTalk View Site Edition and ThinManager

-

Siemens - WinCC RT Professional

-

Schneider Electric [AVEVA] - Wonderware

-

Inductive Automation - Ignition

-

4.6 Substations Interview Questions and Answers

What are the merits of indoor and outdoor substations?

Merits of indoor substations

- Less requirement of space
- Less maintainance
- Less control cable length
- Protection from lightning
- Flexibility in installation
- No dust and dirt

AC Power QA Link

4.7 Substation Engineering Quiz

1. You are building an interconnect station, tying wind farm generation to the power grid. At the substation, the sources are tied through a tie-breaker. Which device would you install to make sure the sources are synchronized? A synchronization check is done using a relay. It needs low voltage input (from both sides), obtained using a voltage transformer a.k.a. instrument transformer.

5 Sources

- Chapter 1
  1. katkimshow Youtube Channel playlist ”Introduction to Power Electronics (2023) for most of the introduction
  2. Why your Function Generator’s output voltage reading can be wrong: section 1.1.1
  3. True, Reactive, and Apparent Power: section 1.2 examples
- Chapter 2
- Transmission and Distribution
  1. Three-phase electric power: Three phase power section
  2. Why three-phase power? Why not a higher number of phases?
  3. Types of Faults in Power System
  4. AC DC Schematics
     (a) Protection & Control Relaying Schematics
     (b) PSRC I5 Schematic Representation of Power System Relaying
     (c) Wiring diagram book
  5. SCADA
     (a) An Introduction to Supervisory Control & Data Acquisition (SCADA)
     (b) SCADA 101: Fundamentals with a Focus on Energy Management System (EMS)
  6. Substation Interview QA
- unfiled
  1. Understanding Impedance Matching

THIS IS A TODO U LAZY MF RE FUCKING ORGANIZE TIHS MESS AND GO THROUGH THESE LINKS TO EXTRACT INFO

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2. link
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