The great DC debate – getting back to the basics

By Anthony Schewitz (ECA Highveld Regional Director)

Reminiscent of Thomas Edison and Nikola Tesla's 'War of the Currents' in the late 1880s, some debate has recently started in the electrical industry about AC vs DC. There seems to be a perception that DC is a 'mystical animal' that electricians cannot understand. There are even some who consider DC to be equivalent to single phase AC – which is very far-fetched – and who attempt to justify this belief with a skewed understanding of the law, not based on fact. Of course, it's complete nonsense as in South Africa DC is used widely in industries in DC speed control circuits and DC motors and so forth. DC is also used commercially in a variety of telecommunication's applications, as well as in computers, LEDs, solar cells and electric vehicles.

Electrical Installation Regulations (EIR)

The EIR does not specifically mention types of voltages and the regulations cover both AC and DC, and only go into more detail in the definitions of the three types of registrations (electrical tester, installation electrician and master installation electrician) and how these are applicable to installations.

> *"electrical installation" means any machinery, in or on any premises, used for the transmission of electricity from a point of control to a point of consumption anywhere on the premises, including any article forming part of such an electrical installation irrespective of whether or not it is part of theelectrical circuit, but excluding*
> *(a) any machinery of the supplier related to the supply of electricity on the premises;*
> *(b) any machinery which transmits electrical energy in communication, control circuits, television or radio circuits;*
> *(c) an electrical installation on a vehicle, vessel, train or aircraft; and*
> *(d) control circuits of 50 V or less between different parts of machinery or system components, forming a unit, that are separately installed and derived from an independent source or an isolating transformer;*
>
> *"electrical tester for single phase" means a person who has been registered as an electrical tester for single phase in terms of regulation 11 (2) for the verification and certification of the construction, testing and inspection of electrical installations supplied by a single-phase electricity supply at the point of control, excluding specialised electrical installations;*
>
> *"installation electrician" means a person who has been registered as an installation electrician in terms of regulation 11 (2) for the verification and certification of the construction, testing and inspection of any electrical installation, excluding specialised electrical installations;*
> *"master installation electrician" means a person who has been registered as a master installation electrician in terms of regulation 11 (2) for the verification and certification of the construction, testing and inspection of any electrical installation;"*

The OHS Act, Regulations and SANS 10142-1 have always been inclusive of both types of currents – and they are dealt with on the basis that both AC and DC can be described as 'current flowing through conductors'. AC and DC are only differentiated when it comes to mixing and ratings because different risks may be present when dealing with either.

History of AC vs DC

There are many documentaries about Thomas Edison and Nikola Tesla's 'War of the Currents'. In a nutshell, Edison developed direct current and, to protect his product, advocated against AC, 'proving' his point that AC is dangerous by publicly electrocuting various animals – including, it is said, an elephant! Tesla, on the other hand, advocated AC, which reverses direction a certain number of times per second and can be converted to different voltages using a transformer. Nearly a century and half later,

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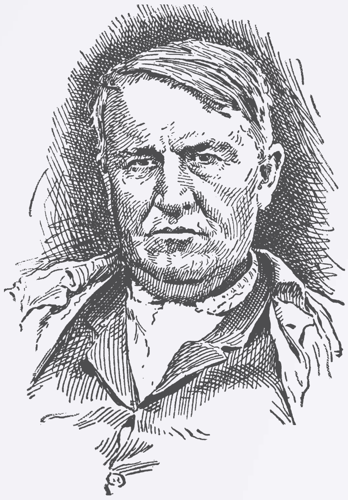
some people are now saying DC has its own unique dangers... The history of Edison and Tesla's War of the Currents is fascinating and, to understand today's debate about AC vs DC, let's look at the facts.



Thomas Edison (February 11, 1847 – October 18, 1931)
"I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that. I wish I had more years left."

Thomas Edison was an inventor and besides the Edison light bulb, he developed direct current – current that runs continually in a single direction – and during the early years of electricity, DC was a standard in the United States. During the War of the Currents, Edison said of Westinghouse that was using Tesla's alternating current: "Just as certain as death, Westinghouse will kill a customer within six months after he puts in a system of any size. He has got a new thing and it will require a great deal of experimenting to get it working practically".

Nikola Tesla (10 July 1856 - 7 January 1943)
"If you want to find the secrets of the universe, think in terms of energy, frequency and vibration."

Nikola Tesla is one of my personal heroes even if he died penniless. Tesla's contributions are lesser known than Edison's although he's now acknowledged as the father of the modern era with his advancements in Alternating current motors, the wireless transition of electrical signals, X-ray, Tesla coils, long distance reticulation as well as a rumoured 'death ray'.

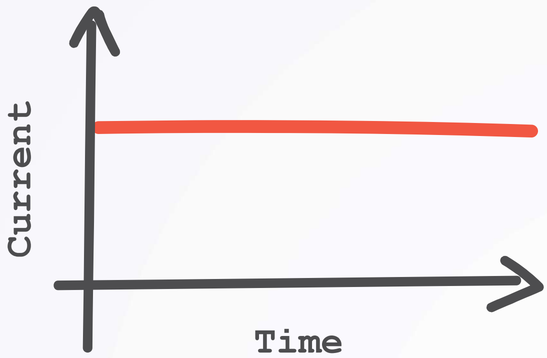
Fundamentals

Fundamentally, the currents are taught in high school science where students must learn about alternating current (AC) and direct current (DC), the base theories and the differences between the two.

The first fundamental principle is that DC is not a phase and cannot technically be constituted as single phase, neither as a base definition or in technical operation.

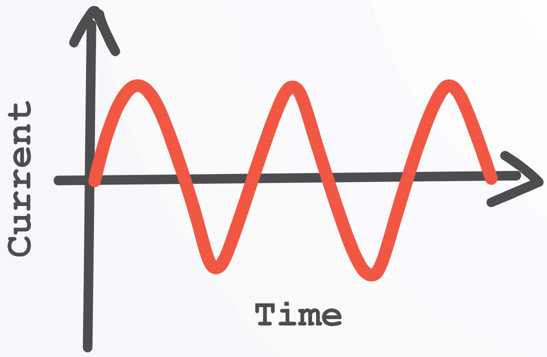
In the Oxford and Meriam Webster Dictionaries, DC is defined as

» *an electric current that flows in one direction only*
» *an electric current flowing in one direction only and substantially constant in value*



Alternating current is defined as

» *an electric current that reverses its direction at regularly recurring intervals*
» *an electric current that changes its direction at regular intervals many times a second*



Therefore, AC is bi-directional. Considering that, can DC then be regarded as the same as single phase? The answer is, from the base definitions, no, it cannot.

Looking at the English language, 'single phase' is a term made up of two distinct terms, where 'single' means:

» *only one*
» *unaccompanied by others*
» *lone*
» *sole*

Phase, by definition, means:

» *a stage in a process of change or development*
» *a particular appearance or state in a regularly recurring cycle of changes*

The English language refers to 'changes' and, if we combine the two words, then it is one set of changes, AC being bi-directional is a cycle of changes, whereas DC is constant, or direct. Thus, by any definition the two cannot be considered the same. They are different in base language, so considering DC to be equivalent to single phase in description would also not align with the base English.

When we look at the definition of 'single phase' in the Miriam Webster dictionary and the words on their own, we notice the specific reference to AC.

» *of or relating to a circuit energised by a single alternating electromotive force*

When going into technical definitions in technical publications the argument runs moot. In summary, the differences are in operation, language and technical perception and they cannot be considered the same. Each has its own inherent dangers and risks.

Risks

When dealing with DC, there is a danger of arcs and the presence of arcs increases the risk of fire. AC does not easily sustain an arc as the current continually changes direction and crosses the 0V line of the sinusoidal wave.

DC sustains arcs throughout operation, but arcs are created in multiple ways, which SANS 60364-7-712 in Annex E describes well and once understood, the risks become evident.

There are three main categories of arcs in PV installations (refer to Figure E.712.1).

- *series arc which may result from a faulty connection or a series break in wiring;*
- *a parallel arc which may result as a partial short circuit between adjacent wiring which is at different potentials;*
- *arcs to earth which result from failure of insulation.*

To protect against these arcs, certain installation methods and selection criteria would have to take place and hence, the standard's additional requirements clarify when, where and how cables are allowed to run ... which could be an article for another day.

DC in the standard

In SANS 10142-1 many would be surprised that DC has been covered for many years under 7.15 and in the adoption of various additional requirements for telecoms, etc.

Cables have never been type-specific as SANS 1507 and SANS 1547 include ratings for both AC and DC and, in 6.2 of SANS 10142-1, installation methods of general cables and current ratings, as well as resistive and capacitive ratings are all documented.

In 2017, we normatively adopted SANS 60364-7-712, which has specific requirements for photovoltaic installations, and adds an additional layer of depth to PV. During the ECA's PV training, we delve deeper into these requirements and unpack them. (These specifications can also be purchased from ECA offices in digital format.)

The PV 'animal'

PV has been a long-standing 'issue' in the electrical industry because there are some people and even institutes who assert that the standards and regulations do not cater for DC. At the ECA, the technical committee still comes across people who have misconstrued the fact that the standards have included DC for many years; and while the standards may need updating, that would be a whole new discussion. PV is covered and is part of the current requirements, and it falls firmly in the framework of installation work in the law.

Does DC need special qualifications? In my opinion, it is not necessary, but training must be standards based and with solar installations on the increase, these requirements must be upheld and enforced.

Given the fact that we have an industry-wide problem where there is a belief that PV is so unique it requires its own separate standard, and some even advocate that the necessary qualifications to work on pv installations should be redefined when, in fact, all that is necessary is to improve and expand the training and standards currently on offer.

Second opinion

For this article, I asked an electrical engineer for a second opinion – Willem Pretorius, Head of Engineering at SolarEFF gives his perspective on the inherent dangers of AC and DC.

AC vs DC

– an engineering perspective

by Willem Pretorius (PREng)

As with many things in life, this topic has many aspects to consider and can be viewed from multiple angles. Two of the largest risk components that need to be considered are: risk to loss-of-life from electric shock and risk to starting a fire (which can lead to multiple loss-of-life). Different physical characteristics of AC vs DC have different effects and influences on these two risk components.

Let's start by evaluating the effect of the frequency characteristic on the human body.

DC (0Hz) causes single convulsive contraction (muscles become shorter and tighter) which pulls the hand away from contact. AC (50Hz) causes tetany (intermittent muscular spasms) leading to a frozen state of muscle movement. This essentially leaves more time for energy transfer from electrical source to human body. Similar to electrical faults, more energy means more damage.

When current passes through the heart, the alternating nature of AC causes arterial fibrillation, which happens when abnormal electrical impulses override the heart's natural pacemaker which can no longer control the rhythm of the heart[1] *[National Health Service United Kingdom]*. The lack of alternation (0Hz) in DC causes ventricular fibrillation, which often leads to cardiac arrest, which is defined as loss of heart function[2] *[Johns Hopkins Medicine]*. The human heart has a better chance of recovery from cardiac standstill (caused by DC) than from arterial fibrillation (caused by AC)[3] *[Electricaltechnology.org]*. This is considering same voltages for both AC and DC and only evaluating the frequency characteristic.

Next let's consider voltage levels. When comparing same voltages for both AC and DC, AC again reveals itself to be more hazardous than DC. The ratings of AC voltages are RMS, which means that the peak of AC voltages is actually higher than the nominal rating. Comparing 230 V AC with 230 V DC, the peak of the AC voltage is actually 325V (Vp= √2*Vrms) and the peak for DC voltage is still only 230 V. A higher voltage (potential) leads to a higher chance of electrocution since the body's resistance is more easily overcome.

Considering practical applications, AC and DC voltages are frequently different. In the solar industry, DC stringing of PV modules are typically designed at 1 000 V. This is significantly higher than practical AC voltages utilised in South Africa. Practically, this higher DC voltage is more hazardous (in terms of overcoming body resistance) than the nominal AC voltages.

Next, protection is considered. In large commercial solar systems, the first line of protection on the DC circuit is at inverter level, via fuses or some sort of smart control. This leaves the whole DC run as a high-risk area, since all panels in each string, as well as the DC cable run to the inverter are electrically upstream of the protection devices. In contrast to this, any section of an AC circuit *should* be downstream of a protection device. Clearly in this case the DC source has a much higher risk compared to AC.

Now we will evaluate arc faults: When a fault occurs that causes arcing, DC is considered to be much more dangerous than AC. AC arc faults tend to self-extinguish (as the waveform passes through zero) whereas a DC arc persists. Considering this and the no-protection section mentioned above, DC can be highly dangerous with significant risk to both loss-of-life as well as risk of starting a fire. This creates the need for superior installation quality as good workmanship is the only control that can reduce the probability of this risk.

Although DC applications have been in existence for several decades and also covered in relevant standards, these applications were mostly low voltage (which is significantly safer than the 1 000 V mentioned above) and in my opinion, it seems like knowledge and experience on DC applications together with their relevant standards are lesser known when compared to AC. Considering that fewer people are familiar with DC applications and their associated risks, it is my opinion and conclusion that DC is more dangerous than AC, at least for the time being.

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2. *https://www.hopkinsmedicine.org/health/conditions-and-diseases/ventricular-fibrillation*
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Two of the largest risk components that need to be considered are: risk to loss-of-life from electric shock and risk to starting a fire (which can lead to multiple loss-of-life).