

## **Discussion on the Definition of “Step Voltage”**

Here are five definitions of the term “Step Voltage”:

### **From IEC 214 (1989)**

“For each value of rated through-current, the highest permissible voltage between terminals which are intended to be connected to successive tapings of a transformer.”

### **From IEC 60214-1 (2003)**

“For each value of rated through-current, the highest permissible voltage between terminals which are intended to be connected to successive taps of a transformer.”

The only difference between the two IEC definitions is that in the second (newer) definition the word “tapings” was changed to “taps.” The meanings of the two phrases are identical.

Here are the definitions according to IEEE C57.131:

### **From IEEE C57.131-1995**

“For each value of rated through current, the highest permissible voltage between successive tap positions.”

“NOTE : Step voltage of resistance type LTCs means tap to tap voltage (no bridging position).”

### **From PC57.131/D1.0 (Revision, Draft 1.0), Sept 27, 2005**

“For each value of rated through current, the highest permissible voltage between successive taps of the transformer winding.”

“NOTE—For all tap changers, the step voltage is the voltage between taps on the tap winding. For resistive type tap changers the output voltage change of the transformer for one tap step change may, at maximum, be equal to the rated step voltage of the tap changer. For reactive type tap changers employing a center-tapped preventive autotransformer to enable a continuous bridging operating position, the output voltage change of the transformer for one tap step change may, at maximum, be equal to one-half the rated step voltage of the tap changer.”

## From PC57.131/D1.1 (Revision, Draft 1.1), Oct 27, 2006

“For each value of rated through current, the highest permissible voltage between tap changer terminals, which are intended to be connected to successive taps of the transformer winding.”

“NOTE—For all tap changers, the step voltage is the voltage between tap changer terminals connected to taps on the tap winding. For resistive type LTCs the output voltage change of the transformer for one tap change operation may, at maximum, be equal to the rated step voltage of the tap changer. For reactive type LTCs employing a center-tapped preventive autotransformer to enable a continuous bridging operating position, the output voltage change of the transformer for one tap change operation may, at maximum, be equal to one-half the rated step voltage of the tap changer.”

The first IEEE definition of the term *step voltage* defines it as a voltage between successive tap positions. The second IEEE definition changes the meaning to be a voltage between taps on the transformer winding. The third (today's) definition refers to the voltage between tap changer terminals.

The purpose of this Working Group discussion is to assure ourselves that this third definition is the one we want, keeping in mind that with the increase in scope of the standard, the definition must be relevant to resistance-type tap changers, reactance-type tap changers, and de-energized tap changers.

In particular, we should determine exactly what is meant by the terms:

1. Step voltage
2. Rated step voltage
3. Maximum rated step voltage

## DISCUSSION

### ***Use of the Term, “Step Voltage”***

The precise meaning of the term *step voltage* is important because tap changers (load tap changers and de-energized tap changers) are assigned a step voltage rating, and it is important to be clear about how the ratings are derived. This discussion covers the meaning and use of the term *step voltage* as it applies to resistive type LTCs, reactive type LTCs, and de-energized tap changers.

### Use of the Term, “Step Voltage,” for Resistive Type Load Tap Changers

The *step voltage* is the voltage between adjacent tap changer terminals according to the IEC version and the latest IEEE definition. But because the tap changer terminals are connected to adjacent taps on the regulating winding, the *step voltage* is also equal to the voltage difference between adjacent taps. And because each tap changer operation moves

the connection from one tap to the next, the change in output voltage for a single tap change operation is also equal to the *step voltage*.

More formally, these quantities are listed below with symbols to represent them:

**Voltages Related to the Step Voltage**

Description	Name	Symbol
The voltage between taps on the regulating winding.	?	V <sub>tap</sub>
Voltage between adjacent terminals of the tap changer	Step Voltage	V <sub>step</sub>
Step change in output voltage after a tap change operation	?	V <sub>change</sub>

For a resistive type LTC,  $V_{step} = V_{tap} = V_{change}$ . So when we limit our discussion only to resistive type tap changers, we may use the term *step voltage* to mean any of the above and still be correct. The step voltage is the change in output voltage for each step of the LTC. The maximum rated step voltage of an LTC is the maximum voltage impressed across adjacent terminals. And the step voltage is the voltage between taps on the transformer winding. When talking about resistive type tap changers, there is no need to be very careful about the way we use the term *step voltage*.

Note that in the above table only the quantity,  $V_{step}$ , has the name *step voltage*. It is assigned that name in the table because there is an official definition of *step voltage* in the standards. The other two voltage quantities are not defined in the standards and therefore are not given names in the table.

### Use of the Term, “Step Voltage,” for Reactance Type Load Tap Changers

Reactance type load tap changers that employ a center-tapped reactor able to carry full load current bring a variation to the situation. For this kind of load tap changer, the bridging position is a continuous operating position, which changes the relationship of the voltages shown in the above table. While for resistance type tap changers,  $V_{step} = V_{tap} = V_{change}$ , now for reactance type tap changers the relationships are:

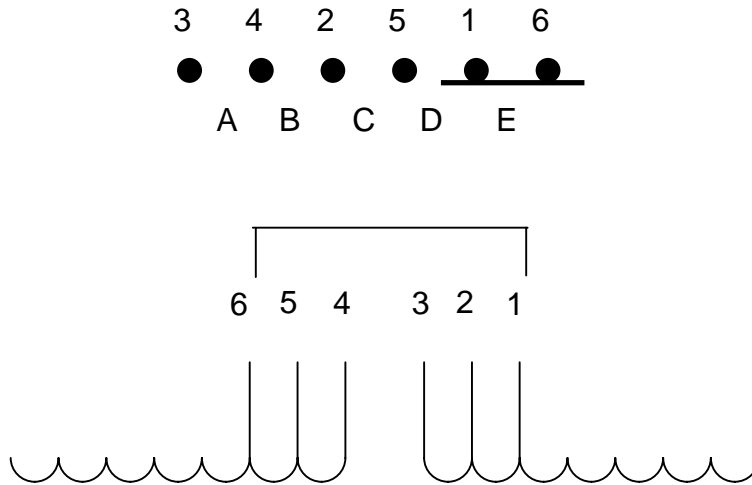
$$V_{tap} = V_{step}$$

$$V_{change} = V_{step} / 2$$

The above is consistent with the definition of *step voltage* given in IEC 214 (1989) and IEC 60214-1, namely, that the *step voltage* is the voltage between adjacent tap changer terminals.

## Use of the Term, “Step Voltage,” for De-energized Tap Changers

With the change in scope of IEC 60214-1 and the revision of C57.131 to include de-energized tap changers, a third variation in the relationship of the voltages defined in the above table enters the picture. The precise meaning of the term *step voltage* is important here because the new IEC standard and the developing revision of the IEEE standard require that de-energized tap changers are assigned a step voltage rating. What that means for a de-energized tap changer is discussed below.



**Figure 1 -- De-energized Tap Changer Connections**

Figure 1 shows a connection and labeling scheme for a de-energized tap changer (DETC). The row of letters identify the tap changer positions. The top row of numbers identify the tap changer terminals. The bottom row of numbers identify the winding taps connected to tap changer terminals with the same numbers. Table 2 shows the voltages between the numbered terminals for each tap switch position A through E. The DETC is in tap position E in Figure 1, but Table 2 shows conditions for all tap positions.

**Table 2**  
**Voltages Between DETC Terminals for All Tap Changer Positions**

Tap Position	Volts 3 – 4	Volts 4 – 2	Volts 2 – 5	Volts 5 – 1	Volts 1 – 6
A	0	1·Vtap	2·Vtap	3·Vtap	4·Vtap
B	1·Vtap	0	1·Vtap	2·Vtap	3·Vtap
C	2·Vtap	1·Vtap	0	1·Vtap	2·Vtap
D	3·Vtap	2·Vtap	1·Vtap	0	1·Vtap
E	4·Vtap	3·Vtap	2·Vtap	1·Vtap	0

Given the definition of step voltage as the “voltage between terminals which are intended to be connected to successive taps of a transformer“, then the above table shows the step voltage for each set of terminals for each tap position. Using the symbols defined in Table 1:

$$\text{Maximum rated step voltage} = V_{\text{step}} = 4 \cdot V_{\text{tap}}$$

and

$$V_{\text{change}} = 1 \cdot V_{\text{tap}}$$

### **WG Meeting, October 23, 2006**

The purpose of the material presented above is to provide background for discussion of this subject at the Working Group meeting in Montreal on October 23.

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October 19, 2006