Transmission System Reliability

An Online Continuing Education Course for Engineers

Course Number: E-2034

Credit: 2 Hours / 2 PDH / 2 CPD

Transmission System Reliability

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Introduction:

Reliability of the system is measured by the weakest link. From a ratings perspective, a circuit that is ten miles long may be limited by a section that is only 50 feet in length. Generation, transmission and distribution systems have different reliability measures and standards. The impact of losing a high-voltage transmission line or a large power plant is more detrimental than losing a distribution circuit.

From a reliability perspective, the transmission and distribution systems perform differently during normal and emergency conditions, during light and peak load. Reliability varies whether the system is overhead, underground or a mix of both. The substation design has a great impact on the overall system reliability; we will discuss common transmission substation designs and compare their reliability.

Transmission System:

By design, transmission circuits are more reliable and robust than distribution circuits; having said that, the capacity of transmission feeders are much larger than distribution circuits, thus losing a transmission line represents a threat compared to losing multiple distribution circuits.

- The inception: most transmission systems start at the secondary side of the GSU located in the power plant switchyard (substation). GSU stands for generator step-up transformer. GSUs step the generated medium voltage (11-22 kV range) to transmission voltage (230-500 kV or higher) to reduce losses (I^2R) and transmit power more efficiently.

- Typical power plants are located far from load centers and since we need to deliver that generated power to the load center, transmission lines may be very lengthy, i.e. a transmission line from Canada to USA.

- The end: transmission systems usually end at a switching transformer located at a remote substation that steps-down the transmission voltage to either sub-transmission voltage or distribution voltage.

- Transmission substation: definitions do vary; transmission substations usually do not have transformers. Of course, all substations will have small Light & Power (L&P) transformers that supply the needed power for station lighting, etc. Transmission stations that have load transformers are typically known as switching stations.

- Common equipment found in transmission/switching substations are:
    - Breakers
    - Disconnect switches
    - Relays
    - Pumping plants (for underground transmission systems)
    - Instrumental transformers (potential and current transformers) mainly for protection and metering.

Substation Design:

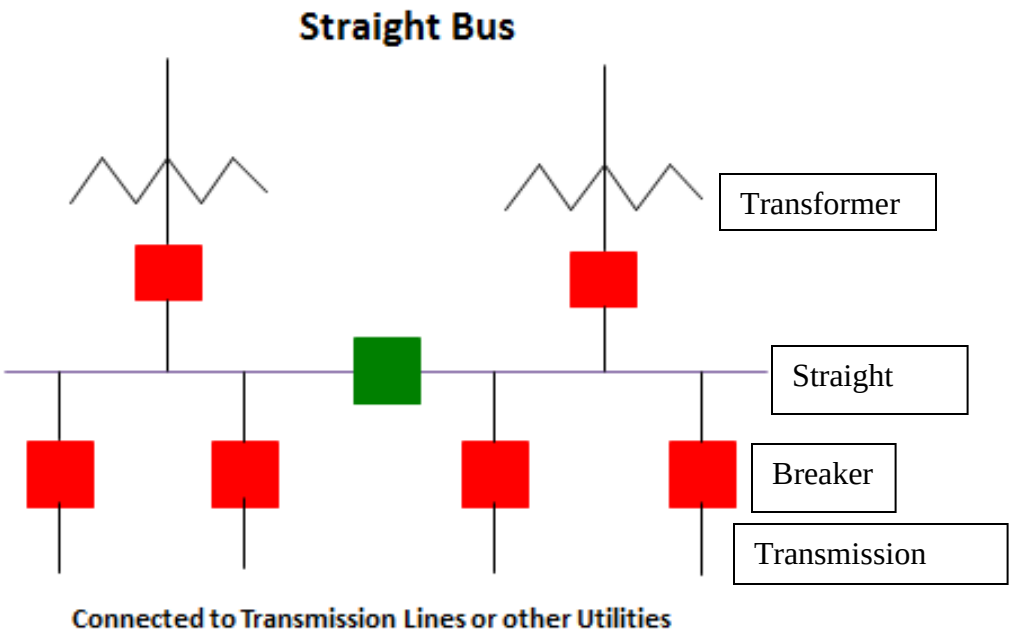
Before we discuss the reliability of the transmission system in more details, we will discuss common transmission substation designs and the reliability of each design.

Straight bus design:

The diagram below depicts a common straight bus design; it is common to represent closed or energized breakers as red rectangles and represent open breakers as green. Substations that will be discussed in this paper can be either AIS (air insulated substations) or GIS (gas insulated substations).

The design below shows the following:

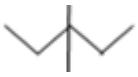
- A straight bus (horizontal line) is typically made of Aluminum.
- There are four transmission lines shown; they are either connected to other transmission substations within the same utility or other utilities, states. Some transmission lines may connect different countries together.



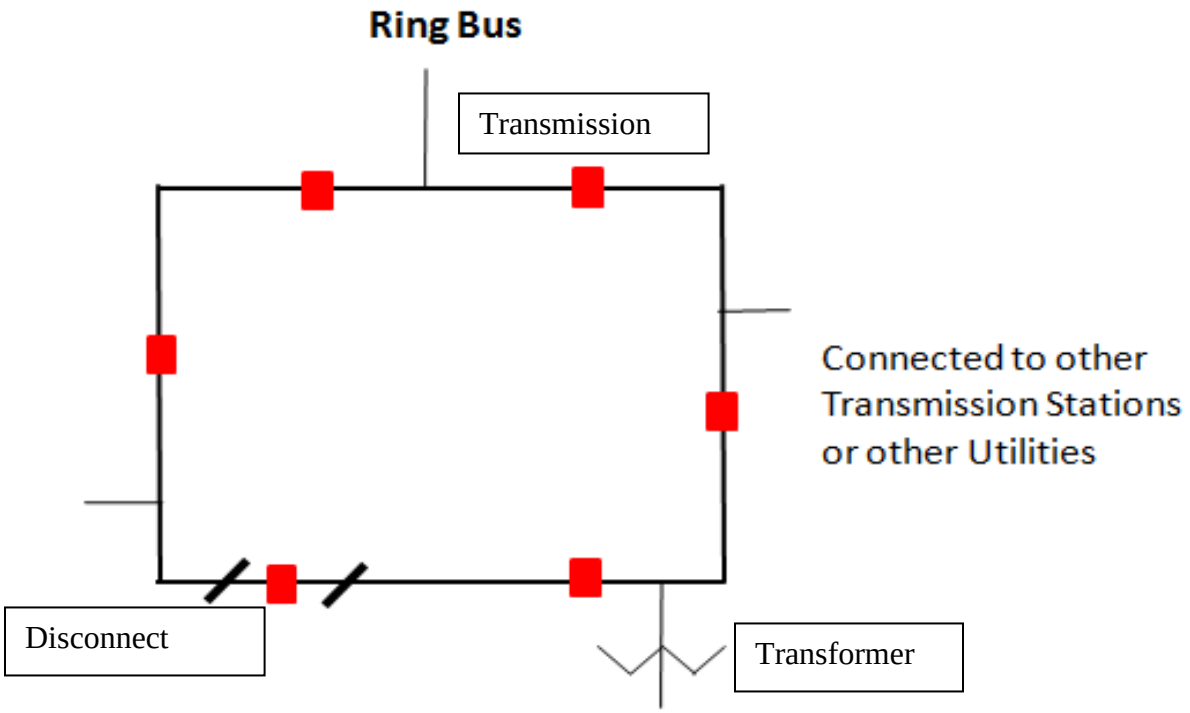
- The bus shown is normally split via the normally open bus breaker (shown in green). There are several reasons why straight buses can have a normally open bus breakers:
    - Short circuit capability is a common reason for having a split bus.
    - Prevent breaker failure; if the bus breaker was normally closed and an attempt to open that breaker failed or if there is a fault that required that breaker to open and the breaker failed to open, then all the other breakers will open, resulting in the loss of the entire substation.
- The straight bus is not very friendly with respect to performing maintenance, where it may be necessary to interrupt the two lines and transformer for bus or breaker maintenance; however, that design is very simple, easily to protect and by far the cheapest.

Ring bus design:

The ring bus design below is more common for transmission bus designs and lately has been adopted for distribution substations as well. The ring bus is more reliable than the straight bus; as seen, there are two directions for power to flow. The (/) symbol shown in the diagram represent a disconnect switch (usually breakers are equipped with disconnect switches on both

sides to allow for isolating the breaker). Transmission lines shown also have disconnect switches unless otherwise noted (not shown). For simplicity, we are showing the symbol for one breaker only; however, all breakers will have disconnected switches on both sides; transformers may have a disconnect switch on the high and/or low side. It is common for transmission stations to have connections to other utilities and sometimes different countries; therefore, this design provides an added reliability compared to the straight bus design. The transformer symbol utilized in this paper is 

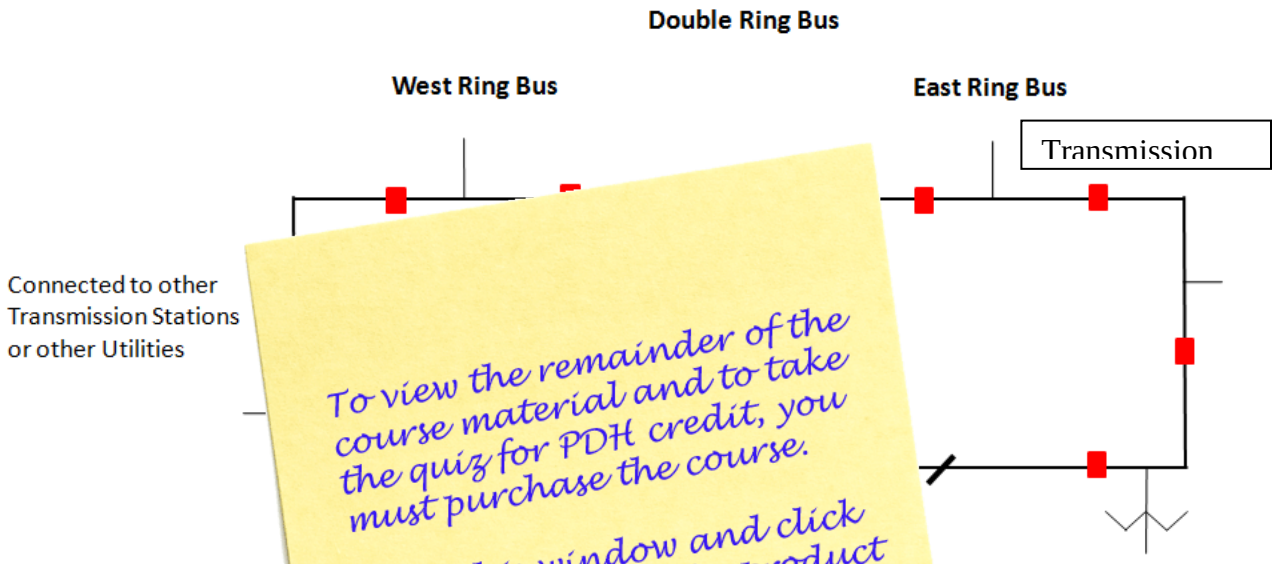
Each line or transformer is protected by two breakers, i.e. when there is a fault, we only lose that faulted line or transformer and no additional lines or transformers are lost compared to a straight bus design where we lost half the station. Depending where the fault occurs, the ring can be further restored after opening the associated dis-connect switch (releasing the feeder or transformer from service).



Double Ring bus design:

Basically, two rings connected via a bus tie breaker. Depending on the available fault current level, the bus tie breaker may be normally open or closed; if the bus tie breaker is open, then each ring operates independently from the other. This mode of operation is common when large power plants are connected to the ring bus, elevating the fault current/short circuit level. Normally there is an existing procedure indicating the conditions when it is permissible to close the tie-breaker, i.e. if a certain generator is off-line (fault current reduction).

If the ring bus tie-breaker is closed, then power can flow from one ring to the other. This design is utilized when the substation has more feeders and/or transformers than one ring can handle, i.e. there are typical rules/guidance governing the maximum number of breakers for a ring bus, i.e. 7 or 8.



Breaker and a Half bus

This is one of the most r as the name implies two lines or two transfo ee breakers. Each component shares a bre The vertical line at both ends is known as the