CONVERTING EXISTING AC TRANSMISSION INTO HVDC (AND BACK)

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ABSTRACT

The paper brief is one out of the first approaches in Turkey to popularize HVDC-light transmissions. It deals with:

1. Lab design and PSCAD modeling of a special bridge controlled AC – DC three load (star-delta) rectifier. It uses 9 group of valves (instead of 6 group valves of common bridge), three lines of former AC transmission, the earth and three DC loads between the lines and earth (or a star-delta inverter).
2. Lab design and PSCAD modeling of a special controlled bridge DC – AC star-delta inverter between three DC source and AC network. It also uses 9 group of valves (instead of common 6 group valves), three input DC lines (and the earth) and three outputs AC transmission lines.
3. Comparison of the bridges construction and modeling results of traditional HVDC-light transmission (6 valves rectifier, traditional DC line and 6 valves inverter) and designed AC-DC-AC transmission (9 valves rectifier, AC line and 9 valves inverter).

The proposed star-delta rectifier and inverter can be implemented in common electrical applications such as HVDC transmission, supply of isolated loads, asynchronous grid connection, infeed of small-scale distributed generators (DG), infeed to city centers, for DC grids, converting the AC lines into HVDC light lines, etc.

INTRODUCTION

As it is known, using HVDC to interconnect two points in a power grid, in many cases is the best economic alternative and furthermore it has excellent environmental benefits. With a HVDC system, the power flow can be controlled rapidly and accurately as to both the power level and the direction. From the other site, in areas where permits for building new AC transmission lines are hard or impossible to get permission, the transmission capacity of existing distribution systems can be increased in a very effective way by converting the AC lines into HVDC-light transmissions.

The other and very important issues of the day are DC light grids creation and the infeed of small-scale DG (usually running asynchronously) to main AC grid. New FACTS techniques (AC-DC and DC-AC converters etc) afford an opportunity to realize the above mentioned problems into practice. Thus, the main advantages [1] of DC transmission compare to AC one are the following:

- Transmission power higher for the same cross-section of conductor.
- Asynchronous interconnection of two AC system.
- Smaller environmental impact.
- No limits in transmitting distance.
- Statistically higher availability and reliability rate.
- Economically more efficient etc.

From AC-DC-AC technology point of view there are three ways of achieving the conversation (1):

1. Natural Commutated Converters (operate with 50-60Hz) are widely used systems today in the HVDC. The main component here is thyristors. It is possible to change the DC voltage of the bridge by means of a control angle and, consequently, to control the transmitting power rapidly and efficiently.
2. Capacitor Commutated Converters (CCC) are characterized by the use of commutation capacitors inserted in series between the converter transformers and the thyristors.
3. Forced Commutated Converters valves operate with high frequency and use semiconductors with the ability not only to turn-on but also to turn–off their currents at any time. They are known as Voltage Source Converters (VSC). Two types semiconductors are used in VSC: Gate Turn-Off Thyristor (GTO) or Isolated Gate Bipolar Thyristor (IGBT). The operation of VSC is achieved by Pulse Width Modulation (PWM), which offers possibility to control both active and reactive power independently and almost instantaneously.

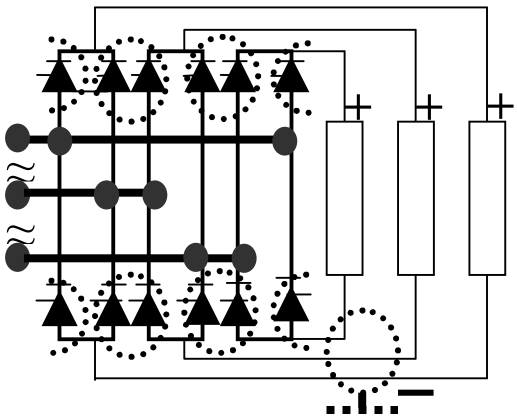


Fig. 1. Three autonomous single-phase DC bridge Rectifiers (rectangle design).

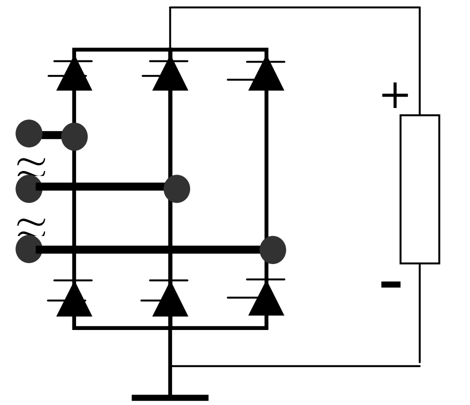


Fig. 2. Three phase DC bridge rectifier (rectangle design).

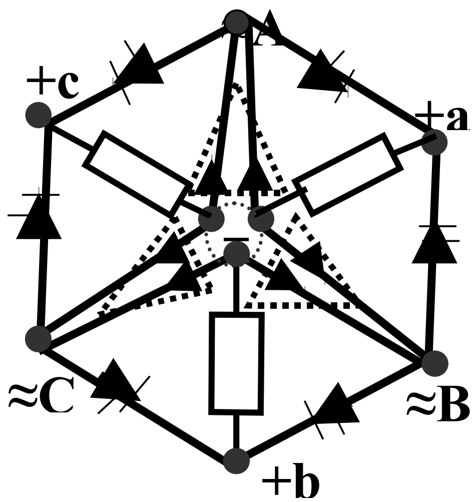


Fig. 3. Transformation of three one phase bridges into a star-delta bridge (hexahedron design).

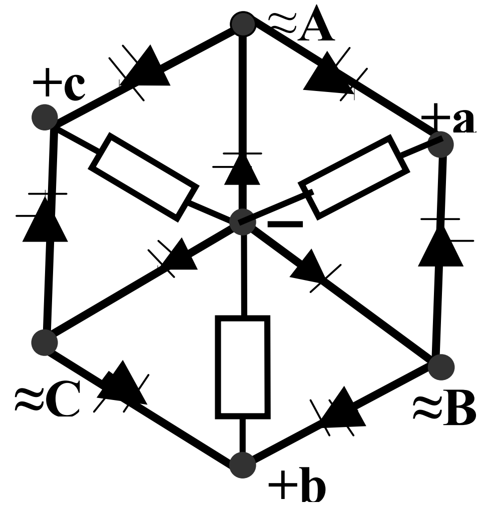


Fig. 4. A star-delta rectifier bridge (hexahedron design).

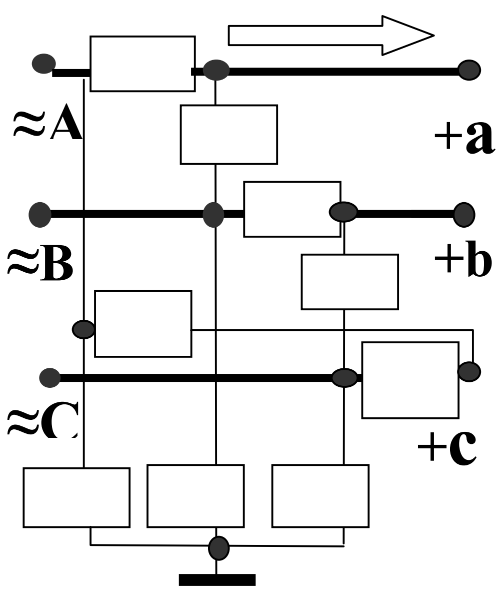


Fig. 5. Star-delta controlled bridge RECTIFIER-switch (normal design).

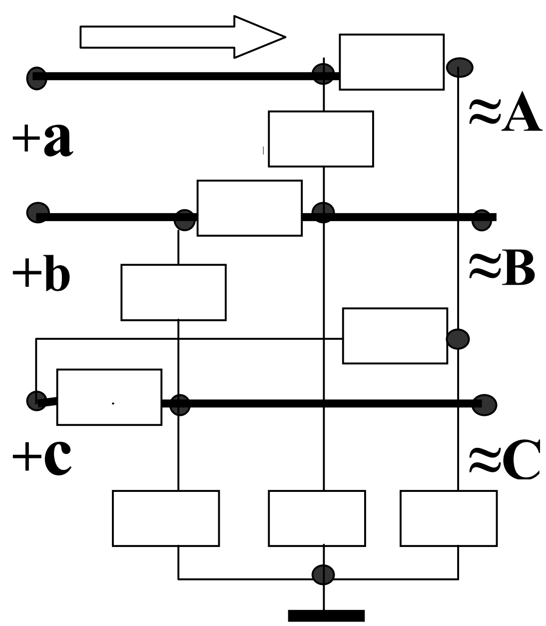


Fig.6. Star-delta controlled bridge INVERTER-switch (normal design).

BODY

Along this paragraph firs of all several traditional rectifying schemes will be described, so in the given application one can be aware of the comparison between the various circuits. Fig. 1 presents three autonomous single-phase AC/DC bridges (rectangle scheme). To make things clear here and later are omitted all AC and DC filters, anti-parallel diodes, snubber circuits, smoothing reactors, shunt capacitors, control systems and the other special for the converters attributes etc.

One may say that the well-known fully controlled three-phase AC/DC bridge rectifier (Fig. 2) can be designed by grouping in Fig.1 (as it is shown by doted lines) the elements of the parallel shoulders of three autonomous single-phase AC/DC bridges. If only the bottom elements of these AC/DC bridges of Fig. 1 are grouped and joined, it can be designed (2,3) the star-delta bridge rectifier (Fig. 3 and 4), which is under consideration in this paper. The same star-delta bridge converter can be designed from well-known controlled three-phase AC/DC bridge (Fig. 2) by splitting each three upper thyristors (divide each into two but cheaper half current thyristors) in terms to supply DC power for three separated loads 3R each. Both thyristors of each new pear control by the same gate signal as their parent thyristor.

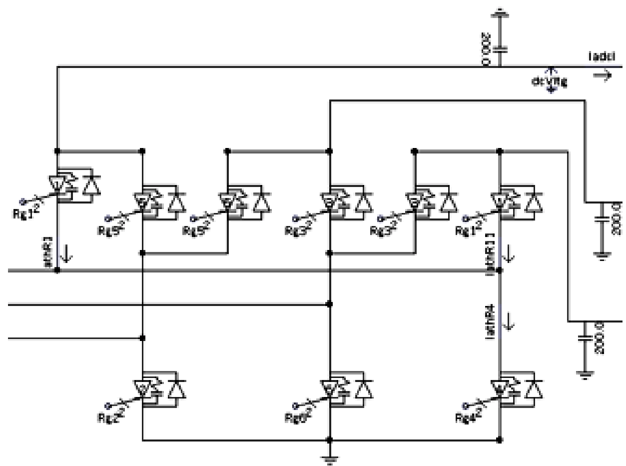
The same approach was applied to similar to Fig.1 and 2 but inverter bridges and similar to Fig.3 and 4 the star-delta inverter bridge was designed. Finally it is presented on the Fig. 5 and 6 more pictorial and convenient schemes of the both converters: the rectifier and the inverter for AC-DC-AC (HVDC-light) power transmission. Turn on/off of each single thyristor is operated from the same traditional angle control equipment as the traditional 6 valves rectifier or inverter bridges.

The main advantage of the designed converters is the following. As stated above (Fig. 5 and 6), the designed AC-DC and DC-AC converters have got three extra bi-directional thyristors per converter (in each phase or line of the converters). During AC-DC-AC (HVDC-light) application they help fully utilize three lines of existing AC as DC transmission (increasing the transmission capacity during asynchronous grid connection). But when a synchronous connection between the systems is possible they help to make quick twist switching to direct AC-AC synchronous transmission.

So, in the rectifier (inverter) there are three common and three bi-directional types thyristors, rated on the nominal current, and three common type thyristors, rated on the half-nominal current. If all thyristors of the converters are bi-directional, the AC-DC-AC (HVDC) transmission will be bi-directional, too.

Lab low voltage (220/380V) and current (around 1-5A) probe tests of these star-delta converters separately and for AC-DC-AC one directional transmission connection on L-R load have shown satisfactory results.
With the aim to get more wide information about transient and steady state regimes of the converters it was made multi variants analysis by the help of modeling software PSCAD V3.0.2 [Educat. Edition].

As the basic AC-DC-AC transmission it was taken the well-known low voltage HVDC educational example: "VSC transmission based on 6-pulse 110kV STATCOM example; it provides up to 75 MW power transmission to the AC receiving end". It was added the same type three IGBTs valves into rectifier and inverter bridges, as well as, the transmission cable was substituted by overhead line with the same resistance (Fig. 7 and 8).



Fig,7 PSCAD model of star-delta rectifier.

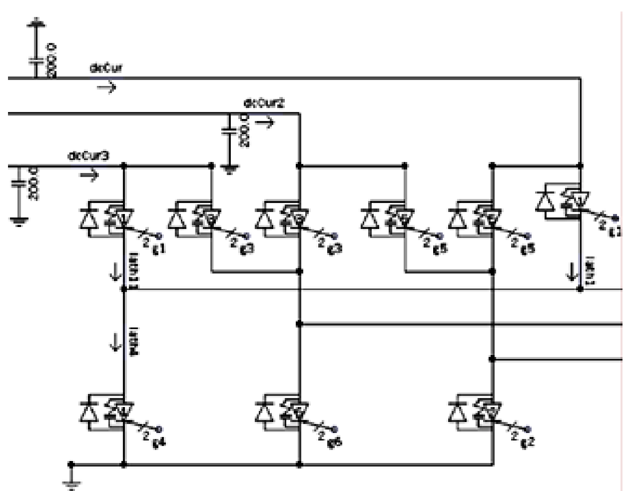


Fig. 8 PSCAD model of star-delta inverter.

Apparent, P-active and Q-reactive powers of the AC-DC-AC transmission during switching-on transient (crossover to steady state) are presented on Fig. 9.

On Fig. 10 is presented inverter-input line-earth DC voltage of the AC-DC-AC transmission system during switching-on transient process (crossover to steady state).

The comparisons have shown that they are just similar to the same powers and voltages of basic HVDC-light educational example. Multi variant analyses by the help of the PSCAD model have verified this AC-DC-AC system working availability.

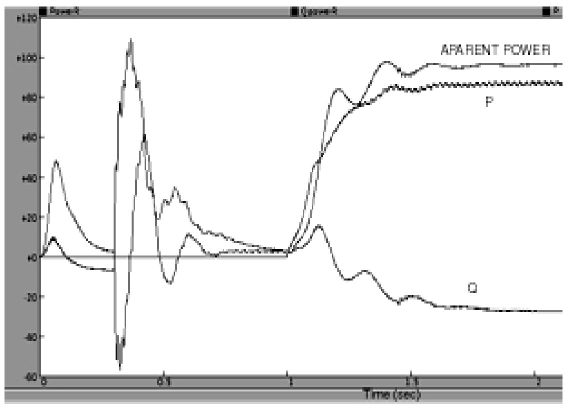
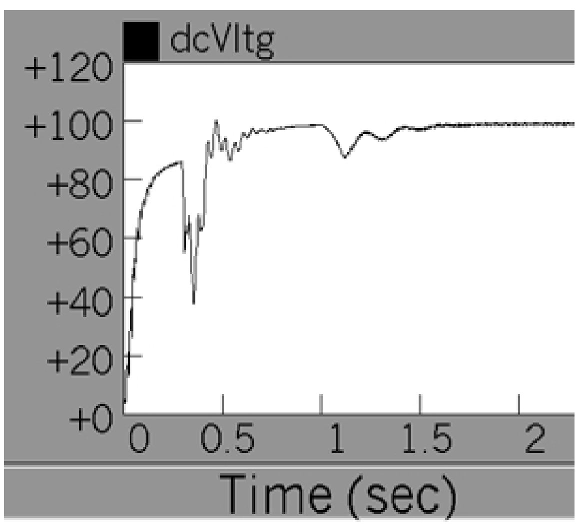


Fig. 9. PSCAD model data: P, Q and apparent power.



CONCLUSION

The proposed star-delta rectifier and inverter can be implemented in common electrical applications such as HVDC-light transmission, supply of isolated loads, asynchronous grid connection, infeed of small-scale generation, infeed to city centers, for DC grids, converting the AC lines into HVDC light lines, etc. (4).

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