A MODIFIED HIGH PULSE ELECTROCHEMICAL RECTIFIER SYSTEM

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Abstract - A novel design of AC/DC rectifier is proposed suitable for large current ratings such as used in electrochemical plants. Essentially, a small circuitry is added to the rectifier conventional circuit to get a higher pulse number of either 18 or 36, yielding high efficiency and a low harmonic content on both the DC and AC sides of the rectifier.

Keywords: Electrochemical Rectifier Systems, Power Electronics.

I. INTRODUCTION

It is a well-known property of rectifier systems that they produce dis-tortion of current waves on the ac supply system.It is also generally recognized that al lwave distortions cause increased operating costs in motors, malfunction of protective devices and increased losses in all system components [I].

In order to diminish distortion, large electrochemical rectifier systems are usually made up of several six-pulse rectifiers, with appropriate phase shift, to create balanced higher pulse systems (12, 18, 24, …., etc.). The proposed confi-guration in this paper works also with a high pulse number, but unlike the conventional configuration, with a notably less complicated circuitry.

Another way of reducing distor-tion, widely used in mid-size rectifier systems, is by means of passive filters. The techniques of applying and designing filters are well established [2, 3]. Besides, they improve plant power factor. Filters, however, present undesired characteristics that merit a comparison with the proposed alternative.

The technique used in this paper was first proposed in the late 1970's and basically allowed the operation of a sin-gle bridge as a 12-pulse converter [4]. In [5] a generalization was attempted based on experimental results, however, only on [6] a complete theoretical treatment is a-hieved, showing all the potential that the tecnique can be put to.

The application of this technique to rectifier systems used in electrochemical installations is addressed in this paper. It is shown theoretically and experimen-tally that 18 and 36-pulse operation ispossible with a slight modification of the conventional configuration.

2.CONVENTIONAL CONFIGURATION FOR 6 PULSOS

The conventional design of recti-fiers used in electrochemical installa-tions is shown in Fig. I. It is a 6-pulse double-wye thyristor rectifier circuit with interphase reactor, and its basic feature is that thyristors are connected to a common busbar for an economic cooling design.

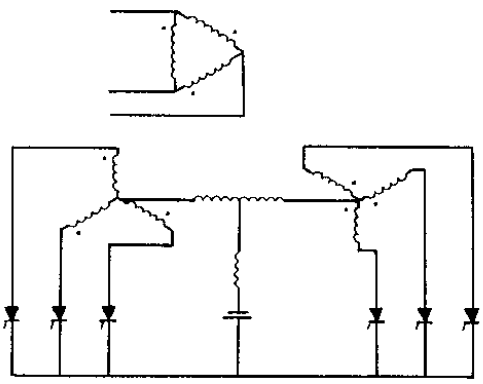


Figura I . Conventional configuration for 6-pulse operation

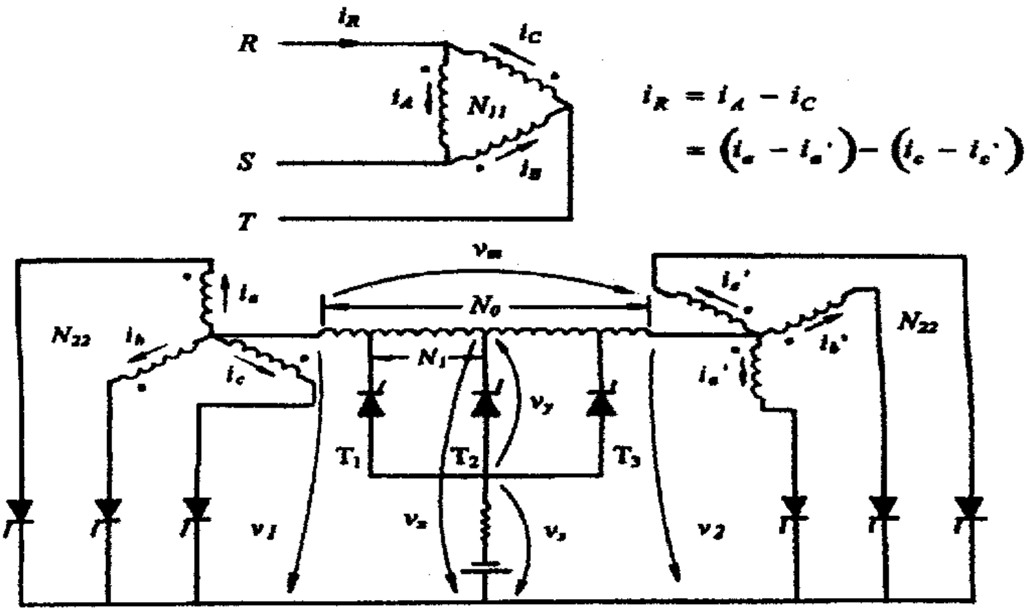


Figure 2 - Proposed configuration for 18 pulses

3. PROPOSED CONFIGURATION FOR 18 PULSES

Fig. 2 shows the proposed configu- ration for 18-pulse operation. Note the small circuitry added. A complete theore- tical treatment is carried out in the fo-llowing section, in order to verify the 18- pulse nature, and therefore remarkable distortion improvement, of the ac input current.

4. AC INPUT CURRENT

4.I Current Analysis on DC Side

In Fig. 3 Iz/2 and iz are currents produced by the conventional configura- tion, whereby the dc output is derived from the reactor centre tap. The superim- posed current ij appears when the output is connected to the other two taps, thus establishing an effective MMF balance.

With reference to Fig. 3, the behaviour of current ij is now considered under the assumption that Iz is perfectly smooth. Equalising ampere-turns when Tl conducts:

(Iz/2+ij)(No/2- Nl) = (Iz/2-ij)(No/2+Nl)
ij = Nl/No . lz (I)

Similarly, when thyristor T3 conducts:

(Iz/2+ij)(No/2+Nl) = (Iz/2- ij)(No/2-Nil)

ij = - Nl/No . Iz (2)

Besides, when T2 Conducts.

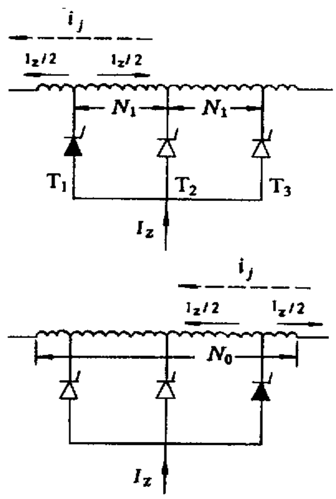


Figure 3 - Currents in reactor

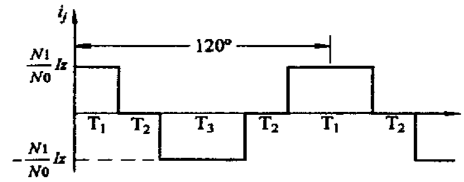


Figure 4 - Composition of ij

4.2 Turn Ratio Nl/No in reactor

A graphic analysis of various voltages on DC side gives a theoretical value of Nl/No=0.3152 [6].

4.3 Current Analysis on AC Side

Current ij with a frequency three times the fundamental,circulates through the appropriate main thyristors and phase windings in anti-clockwise direction, modifying curents in all the windings, including the primary. Fig. 5 shows this effect considering circuit of Fig. 2 under the assumption that $N_{11}= N_{22}$.

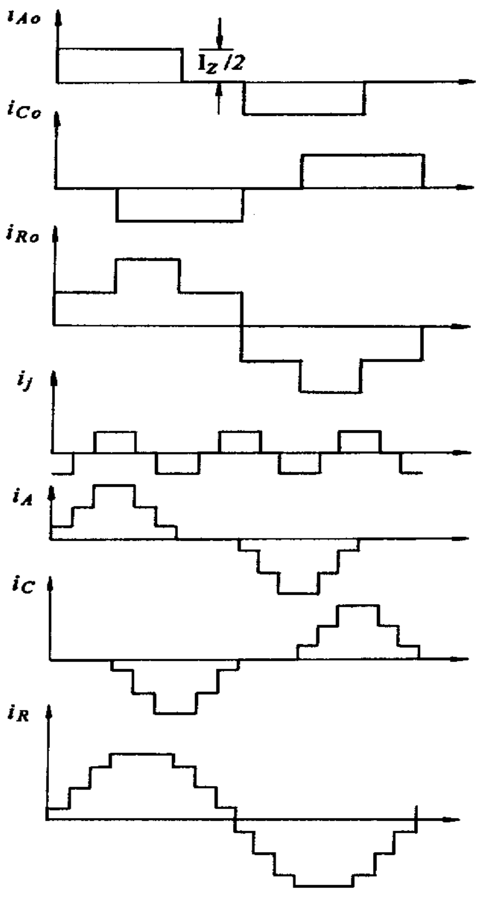
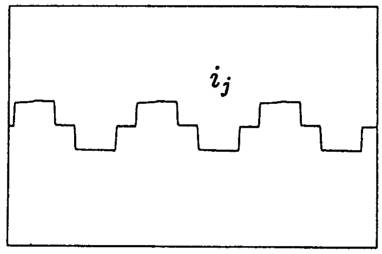


Figure 5 - Theoretical composition of current iR (see Fig. 2)

5. EXPERIMENTAL VERIFICATION

Figs. 6 and 7 show experimental results carried out in a 2-kw laboratory model. Diagrams of waveforms and harmonics were taken using a signal analizer Hewlett Packard 3561A. A comparison between theoretical and experimental waveforms fully validates the theoretical treatment developed earlier.



Figurer 6 - Experimental waveform of current ij

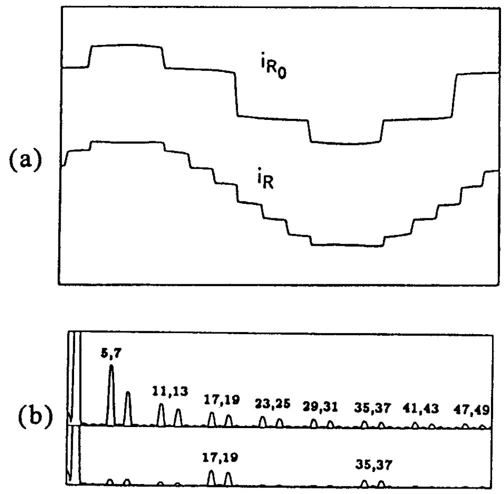


Figure 7 -Experimental ac currents, conventional and proposed configurations (6 and 18 pulses)
a) waveforms b) harmonics

6. PROPOSED CONFIGURATION FOR 36 PULSES

Fig. 8 shows a modification of the 12-pulse conventional configuration to permit 36-pulse operation. This is achieved adding a small circuitry shown in Fig. 8 in dotted lines. It can be demonstrated that in this case N I/No=0.329 [6].

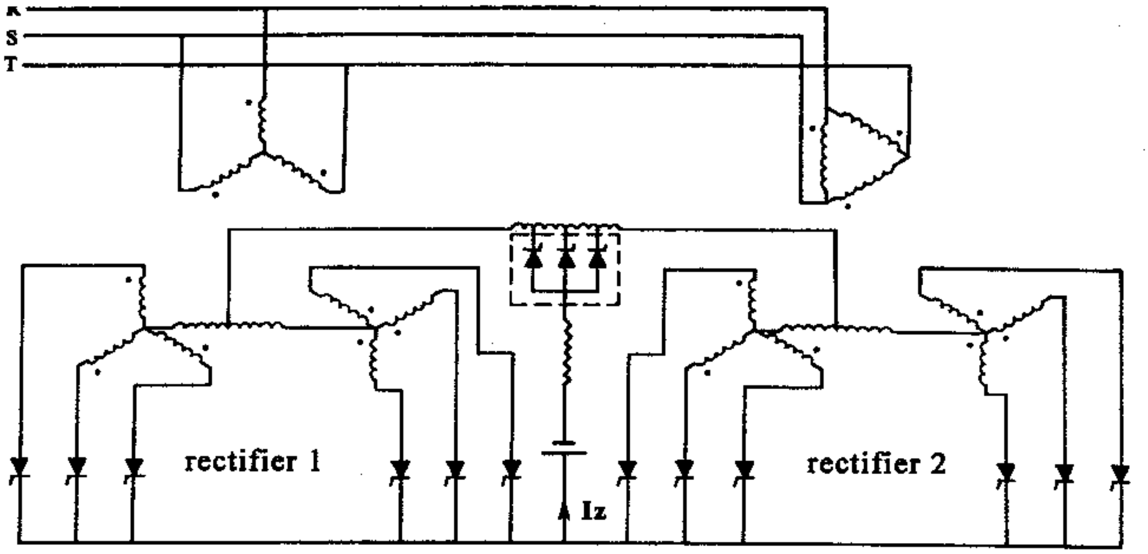


Figure 8 - Proposed configuration for 36 pulses

7. COMPARISON BETWEEN PROPOSED AND CONVENTIONAL HARMONIC ELIMINATION TECHNIQUES

Large electrochemical rectifier systems are usually made up of one or more 6-pulse rectifiers with appropriate phase shift to create balanced higher pulse systems (6, 12,.....,6.n pulses).

Transformer phase-shifting in multiconverter configurations, however, are normally bulky and associated with complicated transformer connections.

Moreover, harmonic elimination isnot complete because there will always be residual harmonics due to imperfect trans- former phase shift, impedance unbalances, for unequal phase retard of thyristors.

In this regard, the notably less complicated circuitry of the proposed configuration, in comparison with the conventional one, is expected to provide a better harmonic cancellation, improve energy efficiency and provide flexibility for a more economic hardware design.

The other alternative of removing harmonic distortion is through the use of passive filtering, using permanently connected inductors and capacitors (a more desired method for mid-size electrochemical installations). Besides, filters improve plant power factor. They, however, present the following undesired characteristics:

a) Filter effectiveness is dependent upon keeping the power system harmonic impedance nearly the same as that assumed in the design stage.

b) Filters detune if the system frequency deviates from its normal value or if filter parameters change with ageing or temperature variations.

c) Filtering may be incomplete because there is a definite relationship between the quality and cost of filtering.

d) Filters do not discriminate between harmonic current sources and they act as a "sink" for the distortion com- ponents produced by other consumers in the vecinity.

In the proposed configuration the harmonic suppression is done by direct cancellation within the converter, therefore avoiding, or at least reducing considerably, the limitations mentioned above.

In general, filter design guidelines for industrial systems are well established

[2], with far less uncertainties found for example in filter design of Hvdc systems. Unlike those, industrial systems are physically compact and normally the impedance networks are dominated by transformers and power factor correction capacitors, which are relatively easy to accurately identify and model [2]. Nevertheless, it is not an easy task, and elimination of harmonics within the converter, as proposed in this paper, seems still a more desirable means of solving the problem.

Regarding reactive power requirements, it must be pointed out that a re-rating of power factor correction capacitors must be carried out to compensate for vars conventionally provided by filters.

Finally, it is important to recognize that the proposed technique also eliminates harmonics on the dc side,providing a smoother dc output current [6].

CONCLUSIONS

A new concept of converter design has been proposed for large current applications such as those involved in electrochemical installations. The proposed configuration, being a slight modification of the conventional one, increases the pulse number to either 18 or 36 and thus, effectively reduces significantly the harmonic content on both ac and dc sides.

The theoretical investigation has been validated in a scaled down experimental model and the results so far achieved are sufficiently encouraging to merit a thorough comparison with conventional alternatives.

Further studies will be carried out to assess the behaviour and overall efficiency of the proposed configuration using a more realistic laboratory model (semi-industrial scale), along with a complete modeling for computer simulation.

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