TEST Engineering & Management

*January – February 2020*
*ISSN: 0193-4120 Page No. 13242 - 13249*

# Investigation of RSUPQC with New Converter Transformer in the Distribution Networks for the power quality Improvement

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***Article Info***
***Volume 82***
***Page Number: 13242 - 13249***
***Publication Issue:***
***January-February 2020***

***Article History***
***Article Received**: 18 May 2019*
***Revised**: 14 July 2019*
***Accepted**: 22 December 2019*
***Publication**: 24 February 2020*

**Abstract**

NCT with Active Compensator (RSUPQC) to provide the compensation in the network to reduce the power quality difficulties. The supply network delivers power supply to various classes of loads like motor drives, with rectifier based design, uninterruptible power supplies etc. NCT have an adoptive wiring arrangement at the secondary portion incorporating two windings with a common linkage point at the interconnection. At the interconnection point a facility is provided to connect the compensating devices has incorporated. The IAF of shunt and series type connected together called UPQC are introduced to reduce the quality problems and to retain the sinusoidal behaviour of the supply to the load end of the power system network. Presentation of NCT with RSUPQC is very much effective when related to olden shunt active power filtering (SAPF) method

**Keywords;** *Power Quality, New Converter transformer (NCT), Inductive Active Filter(IAF), Hysteresis Current controller(HCC),Right Shunt UPQC , PSCAD/EMTDC*

## I. INTRODUCTION

Recent days more electronics devices are being used in a network at load side for improving power transfer capacity and supply voltage improvement. By using such kinds of devices it will brings severe harmonic problems occurs in the system. During conversion process an characterized value of disturbance called harmonics has been generated by the power electronics based nonlinear load. For that reason, it is essential to reduce harmonics in the network if it has not be done it will lead into power quality issues. Filtering method is an way to suppress the quality related problems. Presently, it includes Passive Filter, Active Filter, and Hybrid Active Filter methods [1].

Periodic development of the filters are as follows.1.Passive filters are always present in the grid side of the converter transformer's, and whenever conversion process takes place the harmonics will be generated and the transformer which is present nearer to the switching devices will be badly affected by harmonics and then it lead to a list of problems, such as loss, thermal issues, shaking, and noise. And the next most severe one is the resonance problems occurs between the system impedance and the filter. It introduced an effect of enlargement of harmonic value in voltage &current waveforms, and finally it harms the filters and nearby equipment's. In order to relieve from the resonance problem, the frequency of filter is made somewhat designed to the large value from the overriding resonance frequency. When we done this, it will really worsen the passive filter presentation in the arrangement, and the filtering outcome of traditional passive filter cannot be ideal.

Inductive filtering is a method that can prevent harmonic and components responsible for reactive power compared to the traditional passive filters. This will make the filters arrangement on the extended winding at secondary side so that harmonics flows into the other (Primary) side of the NCT is prevented. It can limits the flow area of the harmonics at the other-side of HVDC system, and the reactive power is is also reimbursed at the nearby the converter side .we can say, present IAF methodology is designed by the harmonic physical characteristics created by the nonlinear load and the tracking of harmonic behaviour modifies based on the load variation.

There APF used are of shunt type reduces current harmonics and active filter of series connected mitigates issues created in voltage related problems. The compensating device called RS -UPQC is a device to provide solution to mitigate quality related issues. This combination of filters of shunt and series type coupled via mutual DC link which rejects the uncertainties spread from the source side and in between supplementary loads. In general, the primary work of UPQC is mitigate quality related issues which has been present in the system and to improve the excellence of supply to consumers.

## II. ANALYSIS OF FILTERING SCHEMES

### A.TCT with PPF

In previous design of TCT at the HVDC Station, the Filters of LC Arrangement are constantly positioned at the network side of transformer is validated in the below figure. Whenever commutation takings place, the generated harmonics currents flows without restrictions at the windings on both sides and it undoubtedly results in creating problems such as losses, increase in temperature, shaking and noise. Finally it increases the design complexity of insulation, rating of transformer and reduces the operating efficiency [3]-[7].

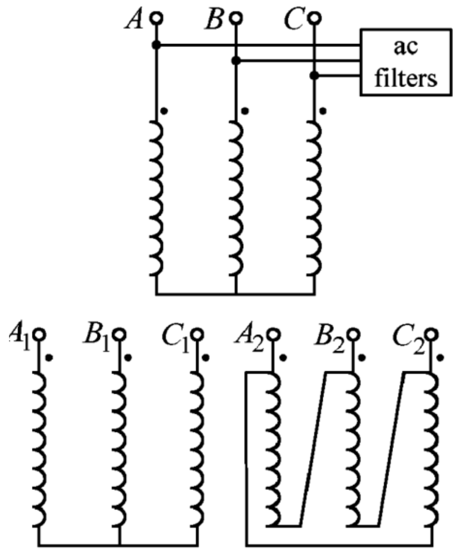


**Fig. 1. Filter arrangement in TCT**

### B.NCT with PPF

From Fig 2 New Converter Transformer (NCT) carries the turn's balance of the transformer at the secondary side so as to connect filters at the same side to suppress these issues. In NCT's a link created at the point of interconnection when we connect secondary extended winding and common winding. This point is established here to connect with LC tuned circuit. Once commutation starts harmonic disturbance generated in the generating source such as converters flows in the secondary extended winding present at the secondary side, when such conditions happens the common winding in the same side will induct an opposed nonlinear current to counter balance it and this can be happened by making impedance value as zero in the common winding and make sure that configuration of LC parameter of the filter is optimal. Hence this method can commendably reduce harmonic current generation at the source point itself and thus it prevents the harmonics passage into the other end of the transformer. But the difficult in this filtering scheme is that it can suppress only static order harmonics like 3rd, 5th, 7th order by the static impedance model of transformer and its regulated branch. The above filtering system with regulated branch design is based on harmonic features by the nonlinear load. If the load has variable nature and it



Published by: The Mattingley Publishing Co., Inc.

January – February 2020
ISSN: 0193-4120 Page No. 13242 - 13249

leads to harmonic generation at a variable rate such that the filtering performance cannot be fully optimal.

### C. Filtering Mechanism

Fig 3 illustrate the one-phase harmonic structure of NCT, and its presence here in the system to inspect the filtering tool. In this figure, $I_h$ indicates current present at the source side and it can have harmonic nature in its presence, which is almost same as current in the extended winding at the secondary side. $I_{h1}$ and $I_{h3}$indicates the nonlinear load current in primary side of transformer and common winding in NCT. Since it has the harmonic source current $I_h$ taken place at the secondary side of extended winding, the primary winding and additional winding at the secondary side will induce a current $I_{h1}$ and $I_{h3}$ to compensate $I_h$ the harmonic current. According to force balance equation, the following outcomes:

$W_2I_h=W_3I_{h3} + W_1I_{h1}$

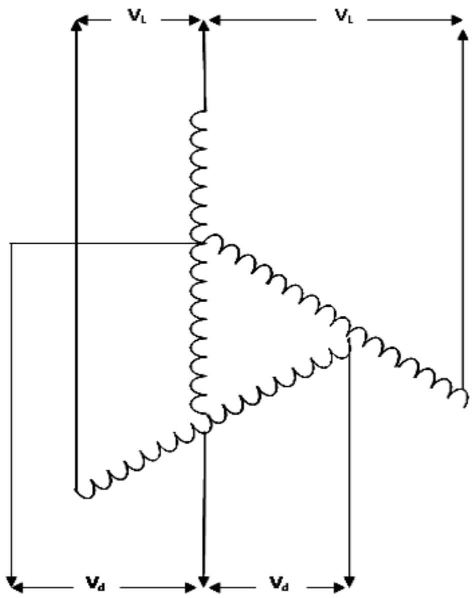


**Fig. 2. Wiring method in NCT**

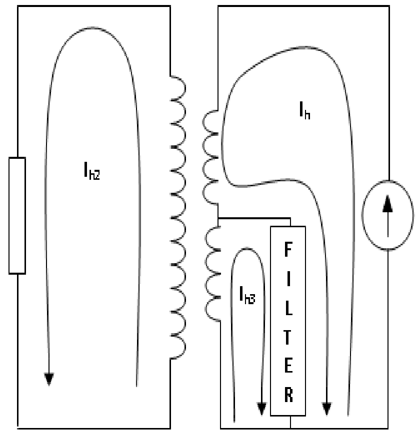


**Fig .3. Single phase inductive filtering model**

in which $W_1$, $W_2$ , and $W_3$ are the winding ratio of the grid side, the extended and common side respectively. If we achieve the balance in the turns of the windings at the either side of the transformer then the generated currents by the load can be balanced, so in the end the value of $I_{h1}$=0, then there is nil opportunity of induced harmonic current at the other endof the transformer. From this we can say, the disturbance can present only at the source side of the NCT and it will not reach through the opposite side. To study the above concept of filtering, it not only wants the complete regulation of filter, additionally it also have the zero impedance rate of common winding of NCT [3].

### D.New Converter Transformer having APF

To overcome the effects of the previous methodologies, an inductive AF method is proposed. In this methodology the Active Filters concept is applied to reduce the power quality difficulties in the supply network. This active filter technology can follows the operational changes happens whenever harmonic generation takes place in the nonlinear load present in the distribution networks and provide a effective filtering performance in the supply system [2].



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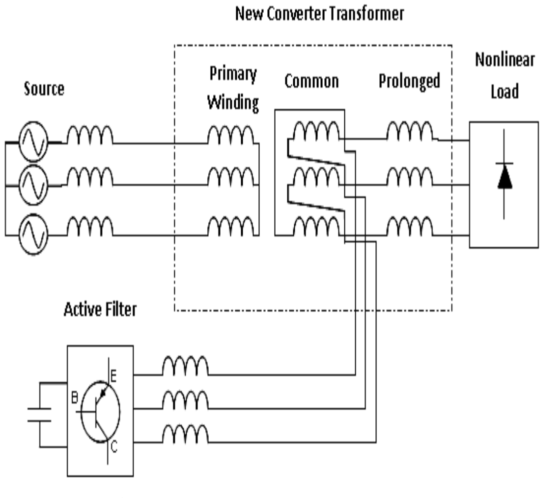


**Fig. 4. Wiring Arrangement of IAF**

In addition to current quality problems there is one more issues present in the supply network which is the voltage quality problems, the above filtering methods are not effective and improve the voltage quality issues of the distribution networks. So to concentrate the both the issues we implement the NCT connected with RS - UPQC. As UPQC consists of combination of series and shunt type active power filters connected together via a mutual DC link. By having such arrangement at the network it can suppress the voltage and current quality problems.

### E. Analysis of New Converter Transformers with Right shunt UPQC

UPQC is a device present in the distribution network and this device has been made by combining the filters of series and parallel type, linked like end-to-end manner, and shares mutual DC link. The UPQC series sections is made to minimizing source side abnormalities like sags & swells, flickering, voltage unbalance etc. It introduce a voltages whenever it is necessary in the distribution network and as a result the load voltages are maintained in an ideal level. Now the other part of UPQC is shunt one and this has made in the structure to reduce the harmonics created in the current portion and when this gets happen it will result in low power factor, unbalance etc. In order to minimize this the opposite currents are same type are generated and it has been injected in the line to retain the load current nearly to a sinusoidal nature. The below figure explains the basic block combination of UPQC where how the SAPF's is connected and they are used to compensate the abnormalities happens in the supply network. A hysteresis current controller is used to control the generation of compensating parameters at the filter end. [5]

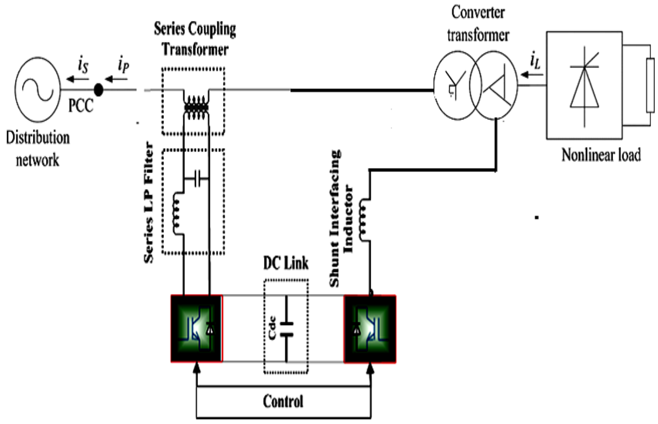


**Fig .5. Wiring Arrangement of UPQC**

## III. MATHEMATICAL ANALYSIS OF SELF COUPLING ACTION

The line-voltage at its output terminals is represented as VL, then Vd is voltage taken at the common winding terminals, Ve is secondary extended winding voltage across its terminals [4]. The phasor representation of secondary winding of NCT is obtained as presented in Fig 6.

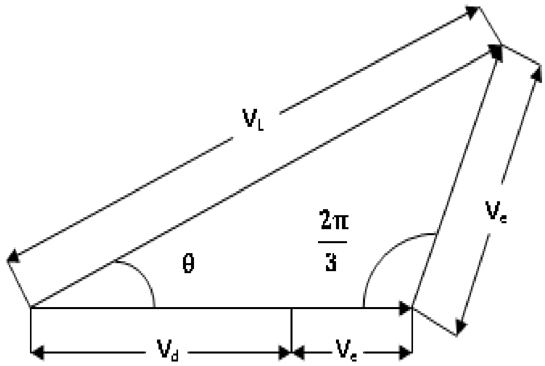


**Fig .6. Voltage phasor diagram of secondary side of Transformer**



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*January – February 2020*
*ISSN: 0193-4120 Page No. 13242 - 13249*

Using cosine rule, the line-voltage is derived as follows:

$$V_L^2 = (V_e + V_d)^2 + V_e^2 - 2V_e(V_e + V_d)\cos\frac{2\pi}{3} \quad (1)$$

The voltage present across the secondary extended winding is expressed as follows:

$$V_e = -\frac{V_L^2}{3} + \sqrt{\frac{V_L^2}{3} - \frac{V_d^2}{12}} \quad (2)$$

The force balance between the secondary sides of NCT is expressed as follows:

$$V_e I_e = V_d I_d \quad (3)$$

Where rms value of $I_e$ and $I_d$ are the currents at the NCT Extended and common winding. The prolonged winding current $I_e$ and output value of current $I_o$ are equal and its electromagnetic capacity is conveyed as follows:

$$S_e = 3V_e I_o \quad (4)$$

The output capacity of the new converter transformer is derived as follows:

$$S_o = \sqrt{3} V_L I_o \quad (5)$$

The material consuming ratio of the transformer is obtained as follows:

$$\alpha = \frac{S_e}{S_o} = \frac{\sqrt{3}V_e}{V_L} \quad (6)$$

Where α - coefficient ratio of NCT.

## IV. CONTROLLER DESIGN

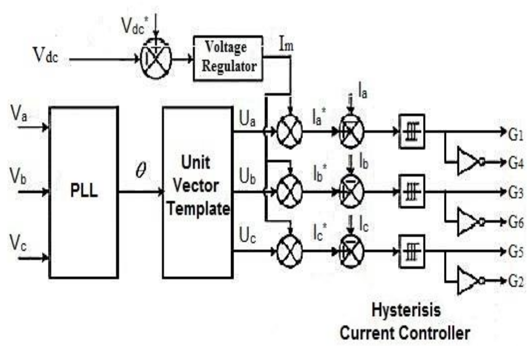


**Fig .7.Controller layout**

The compensation current is injected to the circuit is mainly controlled by the filter circuit. This injected current to the filter circuit pay off the current which is having harmonic content is drawn by the nonlinear load. It also reimburse the reactive power demand which is needed by the nonlinear load.

The control scheme is formed with help of unit vector template and the input supply described in Fig. The unit vector patterns are generates the reference angle which is obtained from PLL.

The unit vector patterns are produced with proper sequence delay as follows.

$$U_a = \sin\theta \quad (7)$$

$$U_b = \sin(\theta - 120^o) \quad (8)$$

$$U_c = \sin(\theta + 120^o) \quad (9)$$

The reference source current is given by DC voltage control loop. The capacitor voltage is compared with error signal with a constant value. The PI controller supplies an error signal.

The controller give the fundamental reference value ($I_{\zeta ref}$) as:

$$I_{\zeta ref} = G_c(V_{dc}{}^* - V_{dc}) \quad (10)$$

This signal is added with the peak magnitude of fundamental load current ($I_{Lfund}$) to compute the reference current at the source section ($I_m$) as follows.

$$I_m = I_{\zeta ref} + I_{Lfund} \quad (11)$$

The reference source current in terms of peak value ($I_m$) is combined with the unit vector patterns (Eq. 9 to Eq. 11) to obtain current signals ($I_{abc}{}^*$) as follows:

$$U_{abc} \times I_m = I_{abc}{}^* \quad (12)$$

The source currents ($I_{abc}$) are being sensed and it has been compared with a value of reference signals. By doing this the error can be found out and it is mentioned as



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January – February 2020
ISSN: 0193-4120 Page No. 13242 - 13249

$$I_{error} = I_{abc} - I_{abc}{}^{*} \qquad (13)$$

From that error signal ($I_{error}$) what we have obtained in the above step can be processed by HCC and a suitable gate signal is generated for the filter to get optimal performance.

## V. SIMULATION RESULTS

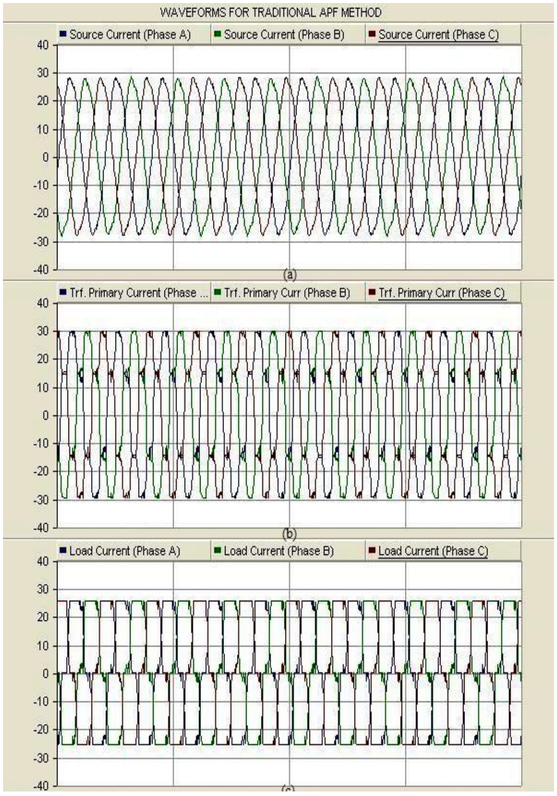


**Fig. 8. Traditional APF – Current waveforms**

Fig 8 show the waveforms of TCT adopted PPF at the primary side which clearly indicates the transformer of both the sides of the transformers are affected the harmonics created by the nonlinear load in the supply network.

Fig 9 shows the waveforms of NCT adopted SAPF at secondary part of transformer windings. From the above graph we can clearly conclude that by adopting this wiring scheme the path of harmonics are restricted at the secondary part of the transformer itself. So that the flow area is minimised.

Fig 10. Voltage Waveforms of NCT with shunt APF. This arrangement connection can only suppress the current harmonics, the voltage related issues are statically existing in the system itself. So we need a special scheme to overcome the above issues.

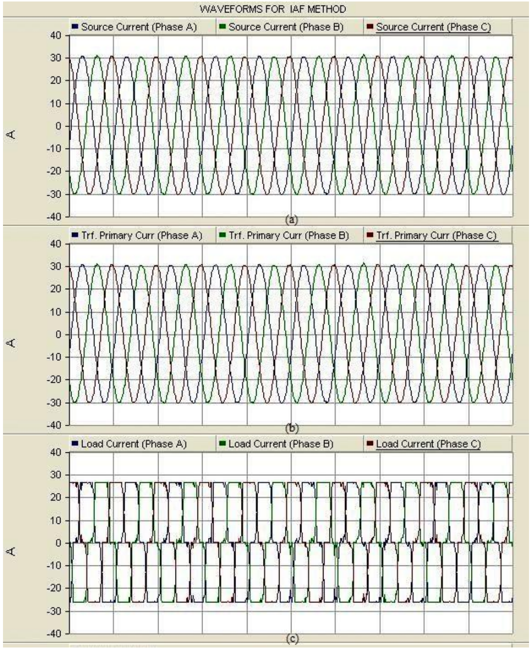


**Fig 9. NCT with APF – Current Waveforms**

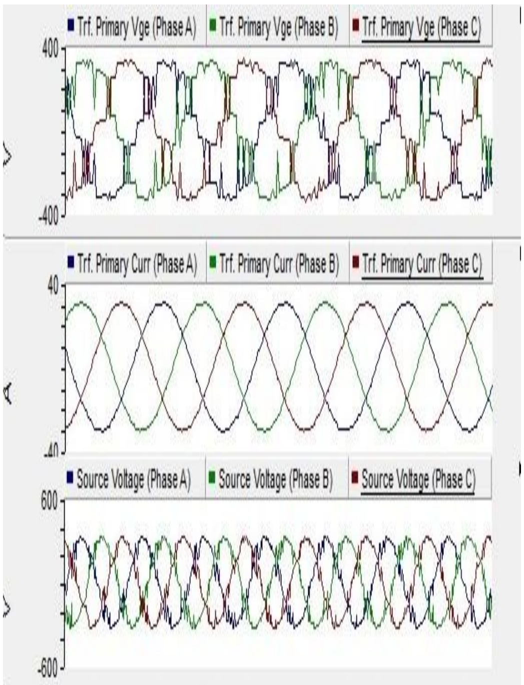


**Fig.10. NCT with APF - Voltage Waveforms**

Fig 11 show the voltage waveforms of NCT with RSUPQC. From this results we can conclude that the voltage output of primary and source sides of the



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January – February 2020
ISSN: 0193-4120 Page No. 13242 - 13249

transformer because almost sinusoidal and which in turn increase the quality of the power in the distribution network.

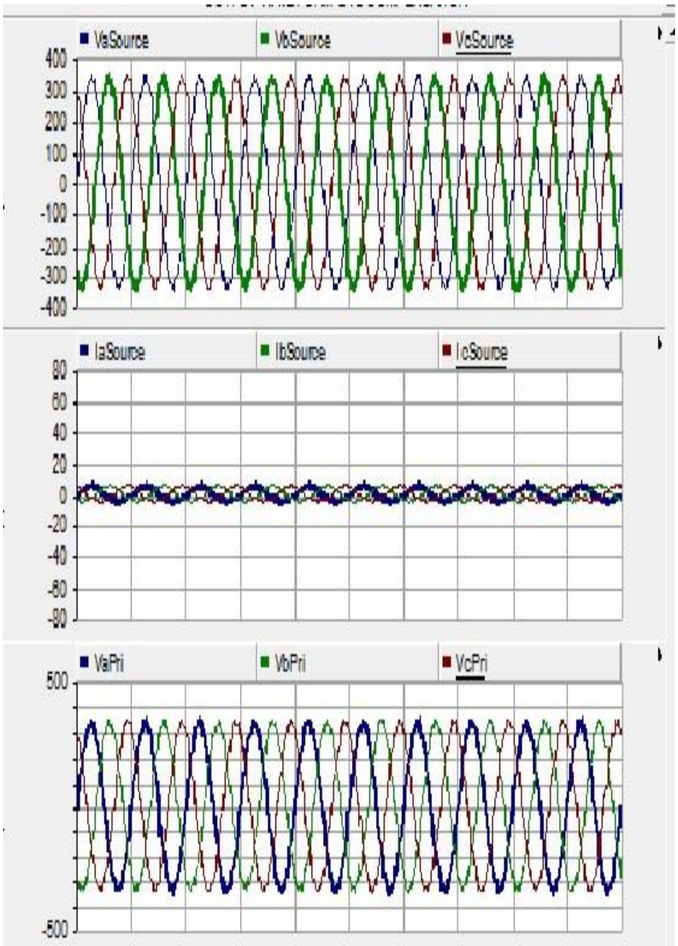


**Fig 11 NCT with RSUPQC - Voltage Waveforms**

## VI. CONCLUSION

This work can majorly explains about the TCT with PPF SAF connected in NCT and interconnected of NCT with RSUPQC is compared. From the results it is apparently proved that from the results the NCT with RSUPQC can effectively solve the issues related to quality of power by providing both voltage and current balance at the supply network majorly at the consumer end. The ultimate aim of this work is reduce the disturbance behaviour at the source side itself by providing a extending winding at the transformer arrangement. So that flow area is restricted at the end and the components connected are completely unaffected from the issues.

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