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Simulink Analysis of Vector Groups of Transformers Installed at 132kV Grid Station Qasimabad, Hyderabad and their Effects on System Operation

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Abstract: ***In this paper we have simulated the vector groups of transformers installed at 132 kV Grid Station Qasimabad Hyderabad Pakistan with the use of MATLAB Simulink Software. We also make some real time changes in the vector groups of the installed transformers and would analyze their effects on the system operation. The main objective of this paper is to understand the vector groups of transformers, their need in the transformer parallel operation and to make comparative analysis by considering different scenarios of vector groups for transformers installed at 132 kV Grid station Qasimabad Hyderabad Pakistan.***

Keywords: Transformer, Vector Groups, Parallel Operation, Voltage Dip and MATLAB software

1. Introduction

The windings of three phase transformer can be connected in different ways so as to meet the application requirements [1]. Based on these connections of transformer, vectors groups are specified for transformer on its name plate. Actually vector group represents the phases shift between the primary and secondary winding of transformer according to their connections [2]. The vector groups would necessarily been considered when transformers are required to be paralleled to meet the increased load demand. If transformers of different vectors groups are connected in parallel then large circulating currents would flow between two transformers which are dangerous and unnecessary [3-4]. Since the transformers are used in different power system applications such as; transmission, distribution and insulation. The 132 kV grid station is at distribution level of the power system. Therefore at 132 kV grid station, delta/star connected transformers are invariably used, so as to have three phase four wire system, for supplying single phase as well as three phase loads [5]. Loads at the distribution side are always unbalanced so there is always some current in the neutral wire, which provides return path. Therefore to compensate this unbalanced neutral current, delta side of transformer allows the circulating current to flow through its windings [6]. In electrical power system engineering, vector group is the method for characterizing the high tension (H.T) and low tension (L.T) windings connections of three phase transformers, which is being approved by international electro technical commission (IEC). In practice, the voltage measurements on two sides are used to deduce the vector group from the literature about the vector geometries [7-8].
In this paper the authors have fed the readings to a special purpose MATLAB Simulink Model of 132 kV grid station Qasimabad Hyderabad and confirm the exact vector groups and phase angles by means of simulation results. Also vectors groups of transformers connected in parallel are varied and their effects on system operation are also simulated.

2. General Aspects of Vector Groups of Transformers

2.1 Phase Rotation

According to IEC coding technique, vector groups are represented by letters for each set of winding. The high tension (H.T) winding is represented by upper case letter while low tension (L.T) winding is represented by lower case letter. The phasor related with (H.T) is taken as reference and is stationary at 12 0' clock, while (L.T) side vector is rotating anti clockwise with reference (H.T) vector, to represent phase displacement between two sides of transformers. In the vector group code, the first letter which is upper case is dedicated to (H.T) side, while second letter which is in lower case is for (L.T) side, third letter is related neutral connection especially in case of distribution transformers and then fourth letter represents the phase displacement value between the transformer windings.

Since the phase displacement of vector group is analogous to hour and minute dials movement in the clock, hour dial for (H.T) and minute dial is for (L.T). Each hour is dedicated to 30^0 therefore 1st hour= 30^0, 2nd hour= 60^0 and so on. The sign for phase displacement depend upon the rotation of (L.T) phasor with respect to (H.T), for anti-clockwise it's positive and negative for clockwise rotation.

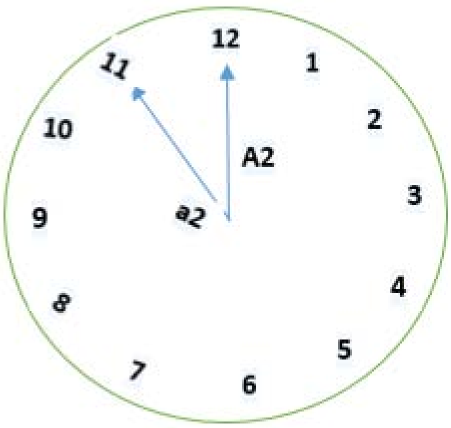

Figure 1: Clock Showing Phase Displacement

2.2 Different Vector Groups of Transformers

Three phase, two winding, power transformers, can be divided onto four major categories as shown in Table 01.

Table 1: Classification of Transformers Vector Groups

Group	0' CLOCK	TC	Vector Rotation
Group I	0 O' Clock , 0°	Delta/Delta Star/Star	Dd0, Yy0, Dz0
Group II	6 O' Clock , 180°	Delta/Delta, Star/Star	Dd6, Yy6, Dz6
Group III	1 O' Clock , -30°	Delta/Star, Star/Delta	Dy1, Yd1, Yz1
Group IV	11 O' Clock , +30°	Delta/Star, Star/Delta	Dy11, Yd11, Yz11

Group I: In this group, high tension (H.T) and low tension (L.T) windings are connected in same fashion either in star/star or delta/delta with zero phase displacement. But by doing some external changes we can designation of this vector group from Dd0 to Dd4 (-120^0) or Dd8 ($+120^0$).

Group II: In this group, high tension (H.T) and low tension (L.T) windings are connected in either delta/delta or star/star with 180^0 displacement, represented as Dd6 or Yy6. By making some changes this vector can be changed to Dd2 (-60^0) or Dd10 ($+60^0$).

Group III: In this group high tension (H.T) and low tension (L.T) windings are connected in different fashion either in Delta/Star or Star/Delta with -30^0 phase displacement. Through some changes, designation of this vector group can be changed to Dyn5 (-150^0) of Dyn9 (+90).

Group IV: In this vector group, high tension (H.T) and low tension (L.T) windings are connected in delta/star or star/delta with $+30^0$ phase displacement. By doing some external changes this vector group van be changed to either Dyn7 ($+150^0$) or Dyn3 (-90^0) connection

3. System Description and Simulink Modeling

At 132 kV grid station Qasimabad Hyderabad, Pakistan, four transformers are installed as shown in Figure A. Three of which are rated at 26 MVA and third one is rated at 40 MVA. They all operate in parallel to supply the cumulative load demand on system. All these transformers have same vector groups i-e; Dyn11, which is key requirement for the parallel operation. But all these transformers have different Iron and copper losses and also the excitation current as shown in Tables 01, 02, 03 and 04.

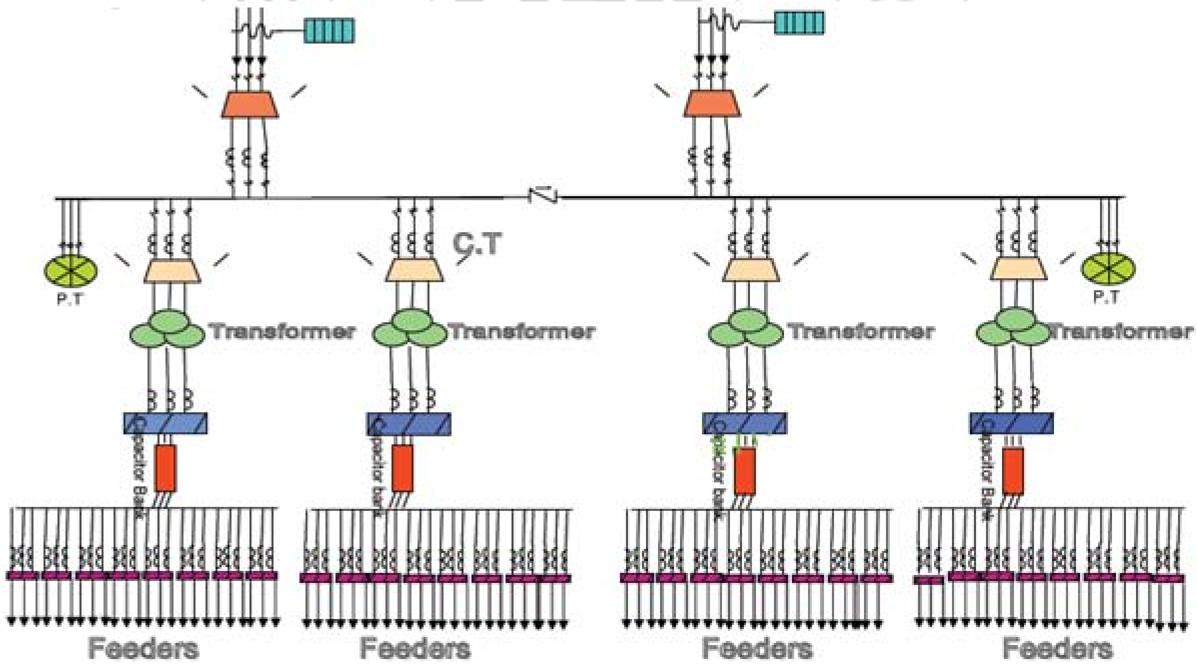

Figure 2: Graphical representation of 132 kV grid station Qasimabad, Hyderabad

Table 2: The Rating of Transformer 1

Description Of Asgen Transformer 2 Of Qasimabad Grid						
Transformer type	TLTN7552	Tap position	H.V Side Voltage	L.V Side Voltage	H.V Side Current A	L.V Side Current
Rated power	20/26MVA	1	145200V	-	80/103	-
Insulation level	A Class	12	13200	11500	87/114	1004/1305
Excitation Current	0.25% at 20MVA	23	118800	-	97/126	-
Iron losses	14.6 kW	Short Circuit Duration			3 Second	
Quantity of oil	20105 Litters	Oil Weight			17669 kg	
Total weight	61500 kg	Vector Group			Dyn 11	

Table 3: The Rating of Transformer 2

Description of Siemens transformer 1 of Qasimabad grid						
Transformer type	TLPN7652	Tap position	H.V Side Voltage	L.V Side Voltage	H.V Side Current A	L.V Side Current
Rated power	31.5/40MVA	1	145200V	-	125.3/159	-
Insulation level	A Class	12	13200	11500	137.8/175	1581.4/2008.2
Excitation Current	0.5% at 31.5MVA	23	118800	-	153.1/194.4	-
Iron losses	22.6 kW	Short Circuit Duration			3 Second	
Quantity of oil	22100 Litters	Oil Weight			19669 kg	
Total weight	73500 kg	Vector Group			Dyn 11	

Table 4: The Rating of Transformer 3

Description Of Iran-Transfo Transformer 3 Of Qasimabad Grid						
Transformer type	TLTN7452	Tap position	H.V Side Voltage	L.V Side Voltage	H.V Side Current A	L.V Side Current
Rated power	20/26MVA	1	145200V	-	80/103	-
Insulation level	A Class	12	13200	11500	87/114	1004/1305
Excitation Current	0.21% at 20 MVA	23	118800	-	97/126	-
Iron losses	12.6 kW	Short Circuit Duration			3 Second	
Quantity of oil	19705 Litters	Oil Weight			16669 kg	
Total weight	59500 kg	Vector Group			Dyn 11	

Table 5: The Rating of Transformer 4

Description Of PEL Transformer 4 Of Qasimabad Grid						
Transformer type	TMAO 26/145	Tap position	H.V Side Voltage	L.V Side Voltage	H.V Side Current A	L.V Side Current
Rated power	20/26MVA	1	145200V	-	80/103	-
Insulation level	A Class	12	13200	11500	87/114	1004/1305
Excitation Current	0.21% at 20 MVA	23	118800	-	97/126	-
Iron losses	12.6 kW	Short Circuit Duration			3 Second	
Quantity of oil	19705 Litters	Oil Weight			16669 kg	
Total weight	59500 kg	Vector Group			Dyn 11	

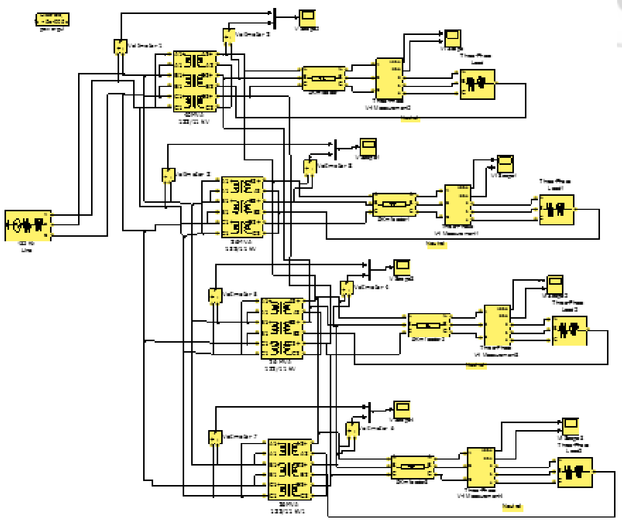

Figure 2: Simulink Vector Group Analysis Design of 132 kV grid station Qasimabad, Hyderabad

Figure.02 represents Simulink model of 132 kV grid station Qasimabad for vector group analysis, consisted of 132 kV incoming line from Thermal power station Jamshoro and Hala Power System. This grid station consists of four parallel connected transformers supplying load, as shown by cumulative loads for each transformer in figure.02. We can notice that, all transformers are connected in Dyn11 fashion, as the star point being connected with ground point of load to suppress the zero sequence currents and also to manage unbalanced loading.

4. Simulink Results

Figures 03, 04, 05 and 06 show phase displacements for transformer 1, transformer 2, transformer 3 and transformer 04 respectively

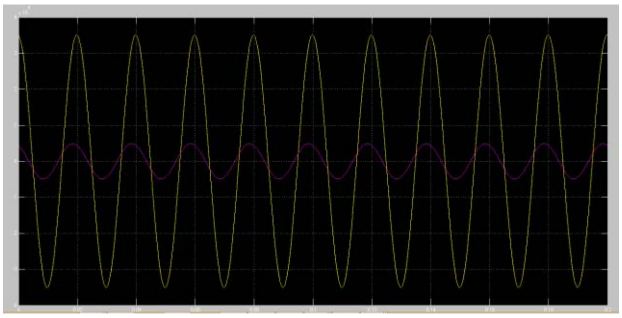

Figure 3: Vector group Phase Displacement for Dyn11 Transformer 1 before changes

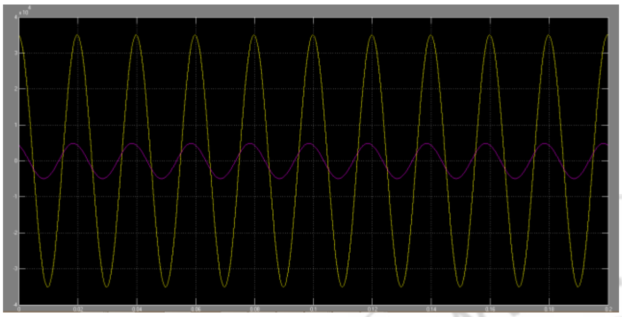

Figure 4: Vector group Phase Displacement for Dyn11 Transformer 2 before changes when transformer 1 is Dyn11 connected

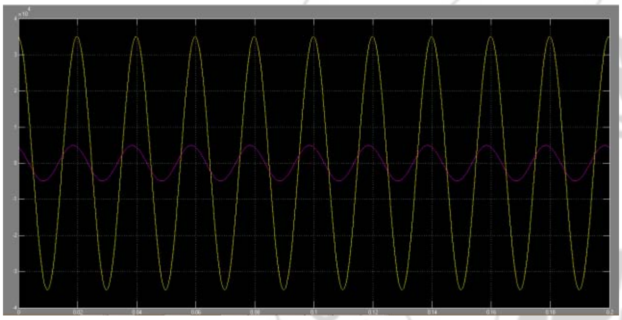

Figure 5: Vector group Phase Displacement for Dyn11 Transformer 3 before changes when transformer 1 is Dyn11 connected

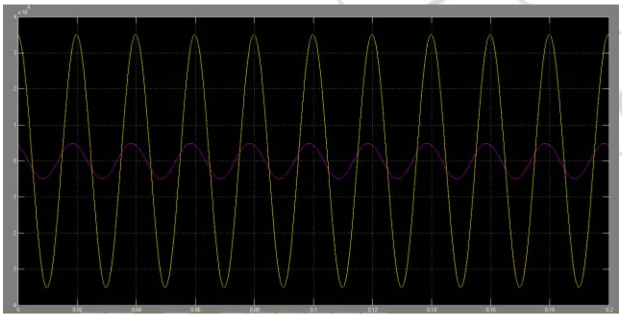

Figure 6: Vector group Phase Displacement for Dyn11 Transformer 4 before changes when transformer 1 is Dyn11 connected

We can see that all figures 03, 04, 05 and 06 have same parameters and Simulink results, it is because all transformers connected at grid station at 132 kV grid station Qasimabad Hyderabad, Pakistan have same vector groups which is the key requirement for paralleling transformers to supply the increased power demand. From these figures we can notice that Low tension (L.T) side voltage lags High Tension (H.T) side by 30 degrees.

Now let's make some changes in the vector groups of transformers connected and compare the actual results of vector groups of transformers. Let's make the Dyn7 be the new vector group for transformer and analyze the results

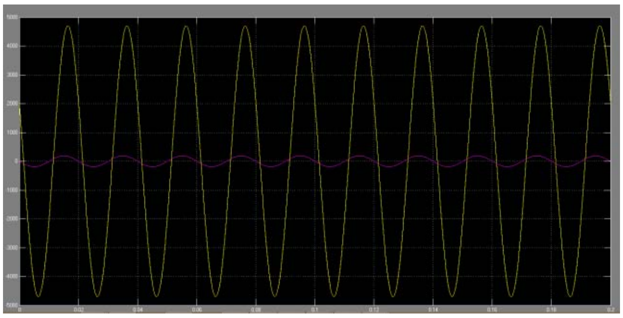

Figure 7: Vector group Phase Displacement for Dyn7 Transformer 1 after changes

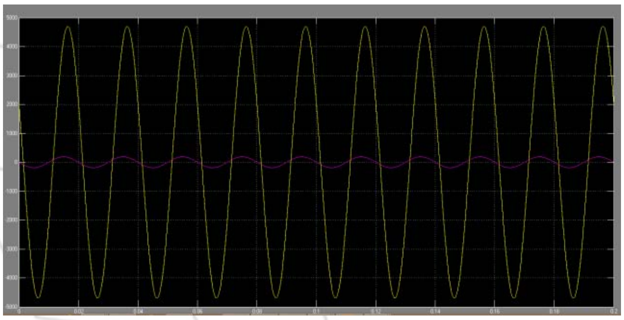

Figure 8: Vector group Phase Displacement for Dyn11 Transformer 2 before changes when transformer 1 is Dyn7 connected

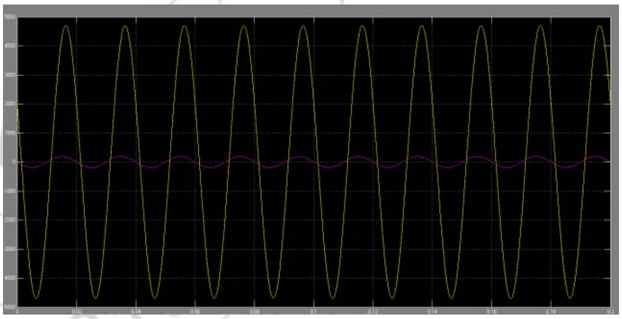

Figure 9: Vector group Phase Displacement for Dyn11 Transformer 3 before changes when transformer 1 is Dyn7 connected

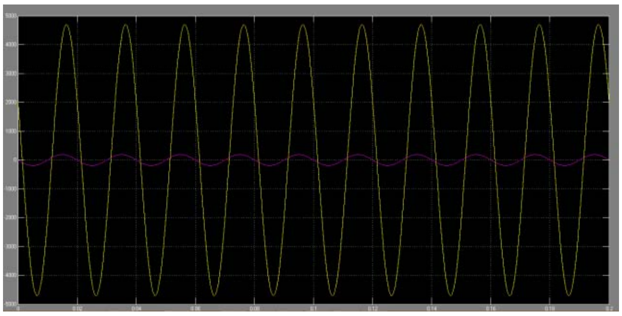

Figure 10: Vector group Phase Displacement for Dyn11 Transformer 4 before changes when transformer 1 is Dyn7 connected

Since when the transformers of different vectors are paralleled then circulating currents flows between them which eventually cause short circuit between the transformers and hence the voltage of the all transformers connected dips down. You can analyze from these effects from figures 07, 08, 09 and 10. We can see that in figures 07, 08, 09 and 10, the high tension and low tension voltages are much less than the voltages in figures 03, 04, 05 and 06, which is only due to these circulating currents caused by paralleling different vector groups transformers.

5. Conclusion

By thoroughly going through these Simulink results we have concluded that all transformers should have same vector groups paralleling transformers. Otherwise large circulating currents will flow and finally they cause short circuit between the transformers. We also found that for the distribution purpose we should select transformer with Dyn11 vector group when generating side is Yd1 connected and Dyn1 vector when the generating side is Yd11connected. This vector group Dyn11 has many advantages such as, it does not allow zero sequence currents to pass across the transformer, and thus the yn side of transformer is separately derived system, in which all earth fault currents must flow through the neutral of transformer. With this configuration, earth fault protection is possible and practical. Likewise, earth fault protection on the primary side is not affected by earth faults on the secondary side of transformer if given transformer is connected in Dyn11 fashion

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