Sweep Frequency Response Analysis for Assessment Deformation Core at Power Transformer

Asep Saepudin, Hilman Sholih, Wilarso*, Asep Dharmanto

Sekolah Tinggi Teknologi Muhammadiyah Cileungsi, Jl. Anggrek, No. 25, Perum PTSC, Cileungsi, Bogor, Jawa Barat Indonesia 1680

**Email: wilarso@sttmcileungsi.ac.id*

Article Information:

Received:
25 June 2024

Received in revised form:
15 Oktober 2024

Accepted:
30 Oktober 2024

Volume 6, Issue 2, December 2024
pp. 110-115

http://dx.doi.org/10.23960/jesr.v6i2.156

Abstract

SFRA (Sweep Frequency Response Analysis) is a transportation test where one of the purposes of this test is to ensure that the core of the power transformer does not shift due to the journey from the factory to the field. The SFRA testing is divided into 4 frequency range areas from 20 Hz to 20 MHz and this research is focused on the frequency range below 2 KHz, based on experience at this frequency to check transformer core problems and specific failures in shifting power transformer cores. Based on the comparison results of SFRA testing carried out at the power transformer factory during the FAT (Factory Assessment Test) with testing in the field during the first SAT (Site Assessment Test) and with the second SAT testing, there are differences in the frequency area below 2 KHz, this shows that there is a problem in the area power transformer core, before drawing a final conclusion that there is a problem or deformation in the transformer core, you must look at the results of other tests carried out in the field such as ratio test, winding resistance test, tangent delta test, excitation current test, insulation resistance (megger test).) winding and core-frame as well as impact recorder data during the journey from the factory to the field. If all other field test results are good then the power transformer is still in good condition and ready to operate and the difference in the graph at a frequency of less than 2 KHz in the SFRA test during SAT compared to when FAT is likely to be caused by residual magnetism that is still on the core side due to testing. DC before or. Residual magnetism can occur due to static electrical phenomena due to the oil purification process or due to the induction effect of the network grounding system where the power transformer is placed.

Keywords: *SFRA, FAT, SAT, Residual magnet, Induction.*

I. INTRODUCTION

The transformer is one of the most important and most expensive equipment in the electrical transmission and distribution system and to ensure that the power transformer is made according to specifications and has good quality, testing must be carried out, there are several tests carried out on the transformer before being sent to the field, be it a special test, type tests or routine tests. Sweep Frequency Response Analysis (SFRA) is a special test carried out on transformers which is carried out during the Factory Assessment Test (FAT) and after the transformer arrives in the field. There are often differences in measurement results in SFRA testing, especially at low frequencies below 2kHz and this is a customer question why this happens [1].

Sweep Frequency Response Analysis (SFRA) is one of the transport tests. SFRA testing is carried out before the delivery of the power transformer during the Factory Assessment Test (FAT) and after the transformer has been seated on a permanent foundation during the Site

Assessment Test (SAT) [2]. The test results before transportation are used as a reference for the results of the SFRA tests afterward. The main purpose of SFRA testing is to determine the physical condition of the transformer, which is to ensure that the internal components of the transformer do not change due to the transportation process or change due to an electrical internal fault when the transformer is operating [2][3][4].

SFRA is a good method for evaluating the mechanical structural integrity of the core, windings and clamping of transformers by measuring the electrical transfer function over a wide frequency range [5], testing SFRA is also one of the parameter methods. In determining the health of a power transformer [6][7][8], Frequency Response Analysis (FRA) is a comparison method, evaluating the condition of the transformer by comparing the data that has been obtained with the same reference transformer in good condition [9]. There are two methods used to analyze the mechanical condition of the transformer, namely Sweep Frequency Response Analysis (SFRA) by injecting AC (Alternating current) voltage with adjustable frequency which is connected to each phase (High voltage) HV and (Low voltage) HV.) LV in open circuit condition [4]. The second method is Impulse Frequency Response Analysis (IFRA) by injecting an impulse into each HV and LV phase with open circuit conditions. In this discussion, we will only discuss the SFRA method [10]. **Figure 1** described main components of transformer are core and winding [11].

Figure 1. Inside power transformer [3].

Figure 2 described Schematic of SFRA testing for transformer.

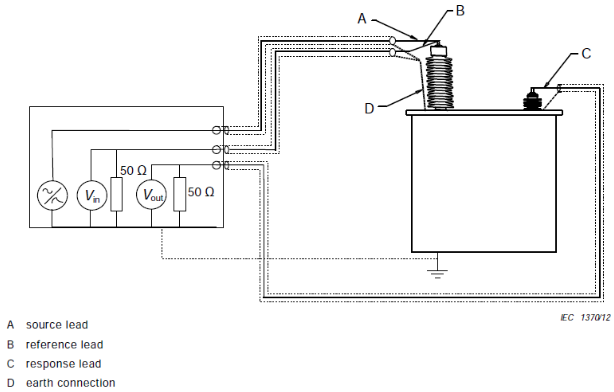

Figure 2. Schematic of SFRA testing [10].

1.1 SFRA Measurement Area

Based on previous experience and research as well as the standards used as reference for SFRA measurements, both IEEE [12] and IEC [13] describe and map 4 (four) frequency range regions that have different sensitivity to deformation or changes in the mechanical integrity of the power transformer as shown. in table 1.

Table 1. The distribution of the frequency range and sensitivity in SFRA measurements [14].

Area	Range	Component Transformer	Sensitive failure
1	< 2kHz	Core	sensitive to deformation core, open circuit, shorted turn and residual magnet
2	2kHz – 20kHz	Between windings	sensitive to deformation between winding to other winding
3	20kHz – 400kHz	Structure winding	sensitive to deformation in structure winding
4	400kHz – 2MHz	Winding tap and test winding	sensitive to position lead winding and lead test

II. Materials and Methods

In this study, sampling of test data at the manufacturer, sampling of test data in the field, comparison of data samples and analyzing the compared data samples [15]. The software, equipment, and power transformer data samples used in this research and analysis are as follows:

1. Software Microsoft excel
2. Laptop DELL Latitude 5480
3. The Sample data testing during FAT and SAT is *Power Transformer* 45 MVA 132/11kV Vector Group Dyn1

Analysis Procedure

The analysis on the Sweep Frequency Response Analysis (SFRA) test is used for the Core Deformation Assessment (Core) on the Power Transformer carried out at PT. X until the conclusion is made with the following stages [16]:

1. Literature study.
2. Preparation of equipment and software.
3. Sampling of SFRA test data during FAT at PT X.
4. Sampling of SFRA test data during SAT that has been sent to PT X.
5. Input the SFRA test sample data during FAT
6. Input the SFRA test sample data during SAT
7. Compare the deviation of FAT and SAT data at frequencies < 2kH
8. Analyze the comparison results with other test results
9. The conclusions of research.

III. RESULTS AND DISCUSSIONS

There are differences in the results of the SFRA test on the Power Transformer 45 MVA 132/11kV Vector Group Dyn1 when testing at PT.X during the Factory Assessment Test (FAT) and during testing in the field during the first Site Assessment Test (SAT) and the second SAT for ensure the difference. The following shows the differences in testing between the SFRA test at the time of the first FAT and SAT conducted on August 26, 2019 as follows: at **Figure 3** described comparison of SFRA during FAT and SAT first time between HV phase A and B.

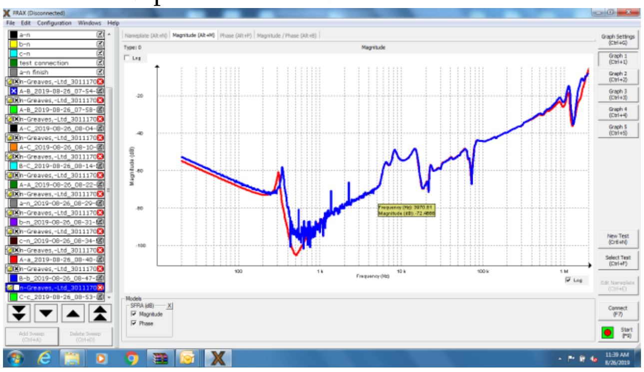

Figure 3. Comparison of SFRA FAT and SAT 1st between HV Phase A-B

Figure 4 described comparison of SFRA during FAT and SAT first time between HV phase B and C.

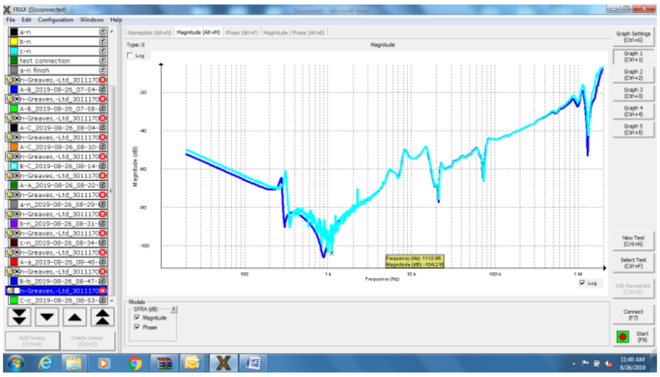

Figure 4. Comparison of SFRA FAT and SAT 1st between HV Phase B-C

Figure 5 described comparison of SFRA during FAT and SAT first time between HV phase C and A.

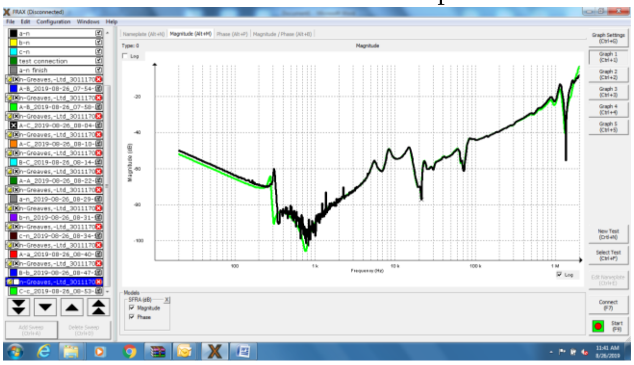

Figure 5. Comparison of SFRA FAT and SAT 1st between HV Phase C-A

Figure 6 described comparison of SFRA during FAT and SAT first time between HV phase A and LV phase a.

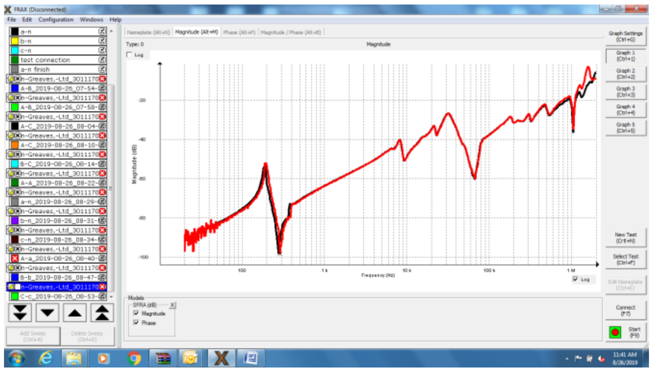

Figure 6. Comparison of SFRA FAT and SAT 1st between HV Phase A & LV Phase a

Figure 7 described comparison of SFRA during FAT and SAT first time between HV phase B and LV phase b.

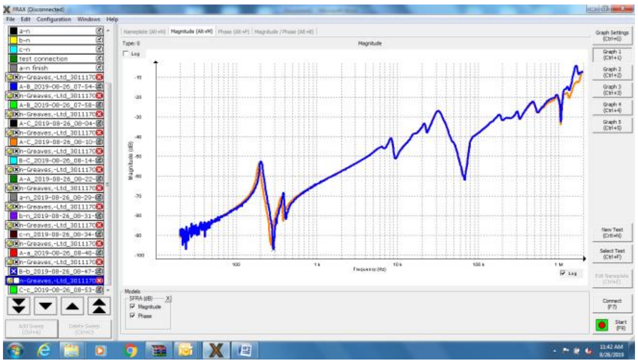

Figure 7. Comparison of SFRA FAT and SAT 1st between HV Phase B & LV Phase b

Figure 8 described comparison of SFRA during FAT and SAT first time between HV phase C and LV phase c.

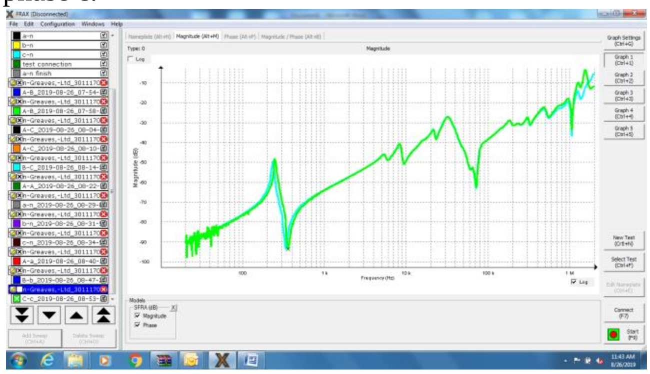

Figure 8. Comparison of SFRA FAT and SAT 1st between HV Phase C & LV Phase c

Figure 9 described comparison of SFRA during FAT and SAT first time between LV phase a and neutral.

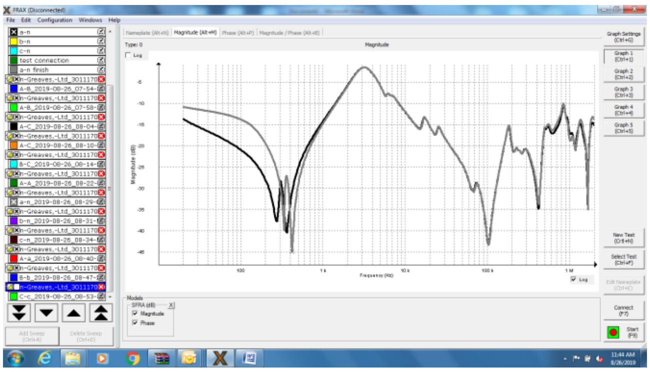

Figure 9. Comparison of SFRA FAT and SAT 1st between LV Phase a & neutral

Figure 10 described comparison of SFRA during FAT and SAT first time between LV phase b and neutral.

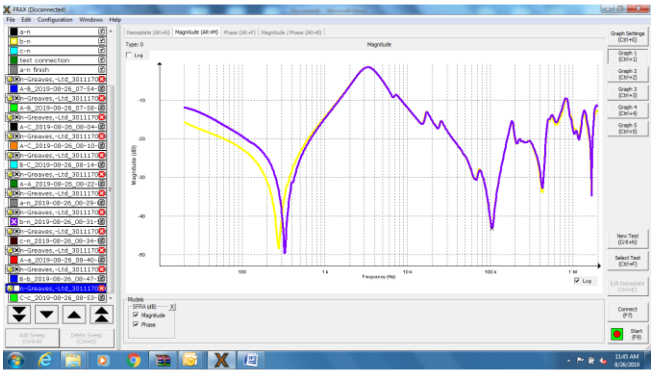

Figure 10. Comparison of SFRA FAT and SAT 1st between LV Phase b & neutral

Figure 11 described comparison of SFRA during FAT and SAT first time between LV phase c and neutral.

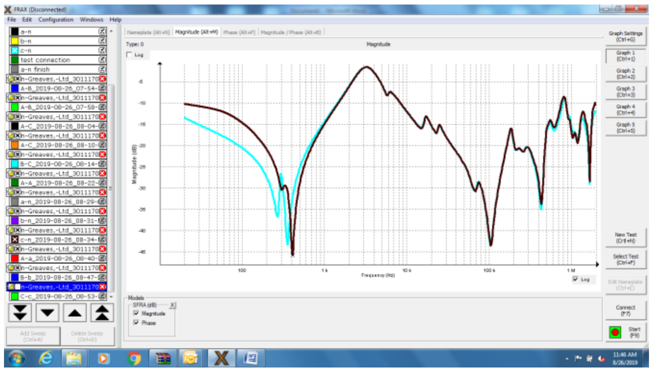

Figure 11. Comparison of SFRA FAT and SAT 1st between LV Phase c & neutral

From the above comparison, the deviation was on <2 kHz area (core side). It was assumed due to remaining flux on core side during SFRA measurement at site.

The following shows the differences in testing between the SFRA test during the FAT and the second SAT which was conducted on 27 August 2019 and also compared to the first SAT which was conducted on 26 August 2019 as follows: at **Figure 12** described comparison of SFRA during FAT and SAT second time between HV phase A and B.

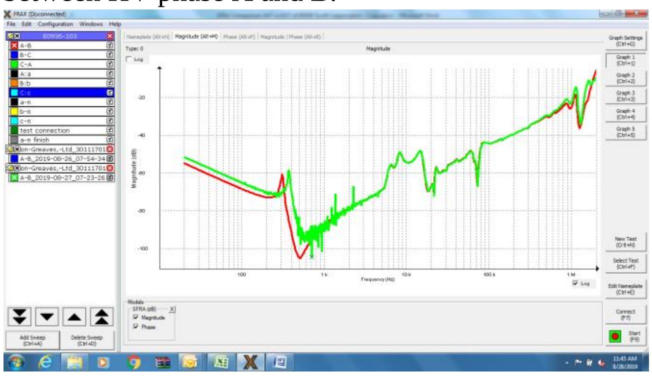

Figure 12. Comparison of SFRA FAT and SAT 2nd between HV Phase A & B

Figure 13 described comparison of SFRA during FAT and SAT first time and SAT second time between HV phase A and B.

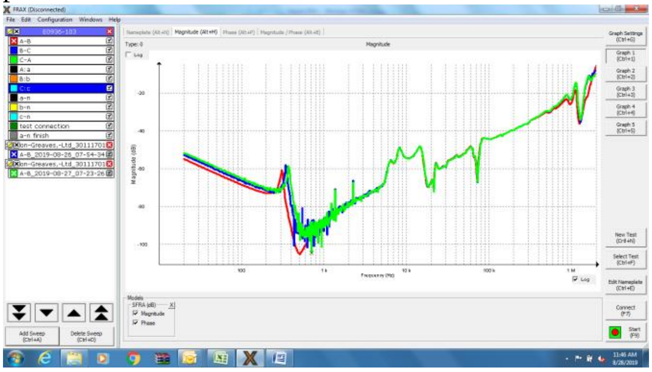

Figure 13. Comparison of SFRA FAT and SAT 1st and SAT 2nd between HV Phase A & B

Figure 14 described comparison of SFRA during SAT first time and SAT second time between HV phase A and B.

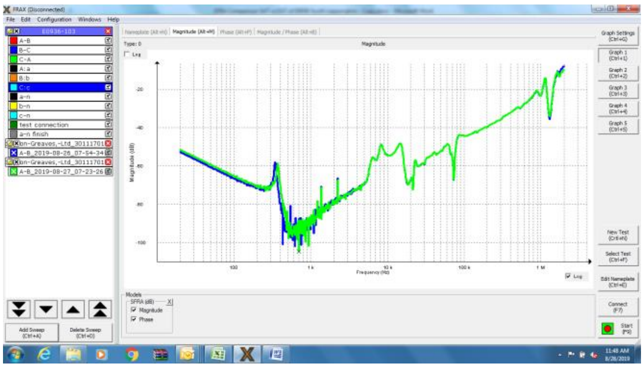

Figure 14. Comparison of SFRA SAT 1st and SAT 2nd between HV Phase A & B

From the above comparison:

- There was deviation on <2 kHz area (core side) between FAT and SAT 2nd. The deviation was same as deviation between FAT and SAT 1st.
- The graph between SAT 1st and FAT 2nd was same (overlay).
- We assume the remaining flux inside core side was still there during SFRA measurement at site although we already try to demag the active part and or grounding lead issue.
- SFRA re-measurement using another SFRA test set brand such as OMICRON or MEGGER is an option.

The other data of power transformer at site for take decision and conclusion from the above comparison SFRA test such as;

- Data of shock log recorder of transformer indicated no significant impact during transportation
- Other site tests show a good result, such as;
    - Insulation Resistance of Winding
    - Insulation Resistance of Core-Frame to ground
    - Turn or Voltage Ratio test
    - Winding Resistance measurement
    - DLA of winding and bushing test
    - Excitation current test
    - Impedance test

IV. CONCLUSIONS

Refer to the SFRA figure and other site tests such as Insulation Resistance of Winding and Core-Frame to ground, Turn or Voltage Ratio test, Winding Resistance measurement, DLA of winding and bushing test and excitation current test which show a good result and also data of shock log recorder which indicating no significant impact during transportation, we conclude that transformer is on healthy condition and there is no evidence of core damage and no deformation on the active part structure inside the transformer winding.

V. REFERENCES

[1] A. Dharmanto and M. Shokeh, “CONSTRUCTION OF POWER TRANSFORMER TANK AGAINST HIGH,” pp. 1–11.

[2] W. Wilarso, “Strength Analysis of Tubular Oil to Oil Cable Box Power Transformer GIS 60 MVA in the Case of Voltage Arc Energy Using the Finite Element Analysis Method,” *J. Eng. Sci. Res.*, vol. 4, no. 2, 2023, doi: 10.23960/jesr.v4i2.111.

[3] Siswoyo, “Teknik Listrik Industri,” Jilid 1., Jakarta: Direktorat Pembinaan Sekolah Menengah Kejuruan, 2008.

[4] J. R. Secue and E. Mombello, “Sweep frequency response analysis (SFRA) for the assessment of winding displacements and deformation in power transformers,” *Electr. Power Syst. Res.*, vol. 78, no. 6, pp. 1119–1128, 2008, doi: 10.1016/j.epsr.2007.08.005.

[5] S. Ab Ghani, Y. H. M. Thayoob, Y. Z. Y. Ghazali, M. S. A. Khiar, and I. S. Chairul, “Evaluation of transformer core and winding conditions from SFRA measurement results using statistical techniques for distribution transformers,” *2012 IEEE Int. Power Eng. Optim. Conf. PEOCO 2012 - Conf. Proc.*, no. June, pp. 448–453, 2012, doi: 10.1109/PEOCO.2012.6230906.

[6] J. C. Gonzales and E. E. Mombello, “Automatic detection of frequency ranges of power transformer transfer functions for evaluation by mathematical indicators,” *Proc. 2012 6th IEEE/PES Transm. Distrib. Lat. Am. Conf. Expo. T D-LA 2012*, 2012, doi: 10.1109/TDC-LA.2012.6319080.

[7] A. et al., “A review on fault detection and condition monitoring of power transformer,” *Int. J. Adv. Appl. Sci.*, vol. 6, no. 8, pp. 100–110, 2019, doi: 10.21833/ijaas.2019.08.014.

[8] S. N. H. Md Mominul Islam, Gareth Lee, “A review of condition monitoring techniques and diagnostic tests for lifetime estimation of power transformers,” *Electr. Eng.*, vol. 100, pp. 581–605, 2018, doi: doi:

10.1007/s00202-017-0532-4.

[9] A. Saepudin, A. Dharmanto, and W. Wilarso, "The Pressure Relief Venting for Air Insulation Cable Box at Power Transformer," in *AIP Conference Proceedings*, 2022. doi: 10.1063/5.0116405.

[10] A. Kraetge, M. Krüger, J. L. Valásquez, H. Viljoen, and A. Dierks, "Aspects of the Practical Application of Sweep Frequency Response Analysis (SFRA) on Power Transformers," *CIGRÉ 2009 6th South. Africa Reg. Conf.*, pp. 1–10, 2009, [Online]. Available: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Aspects+of+the+Practical+Application+of+Sweep+Frequency+Response+Analysis+(+SFRA+)+on+Power+Transformers#0

[11] A. Saepudin, "Optimalisasi Material Utama Pada Auto Transformator 100 MVA," *TEKNOSAINS J. Sains, Teknol. dan Inform.*, vol. 7, no. 1, pp. 1–7, 2020, doi: 10.37373/tekno.v7i1.2.

[12] IEEE Power and Energy Society, *IEEE Std C57.149-2012, Guide for the Application and Interpretation of Frequency Response Analysis for Oil-Immersed Transformers*, no. March. 2013.

[13] 60903 IEC, *International Standard International Standard*, vol. 2003. 2003.

[14] M. A. Habibi *et al.*, "The study of sweep frequency response analysis for inspecting the performance of transformer," *J. Phys. Conf. Ser.*, vol. 1595, no. 1, 2020, doi: 10.1088/1742-6596/1595/1/012016.

[15] W. H. Tang, A. Shintemirov, and Q. H. Wu, "Detection of minor winding deformation fault in high frequency range for power transformer," *IEEE PES Gen. Meet. PES 2010*, no. July 2010, 2010, doi: 10.1109/PES.2010.5589573.

[16] M. A. Habibi *et al.*, "The study of sweep frequency response analysis for inspecting the performance of transformer," *J. Phys. Conf. Ser.*, vol. 1595, no. 1, pp. 0–9, 2020, doi: 10.1088/1742-6596/1595/1/012016.