Al-Rafidain Engineering Journal (AREJ) Vol.26, No.2, March 2022, pp.99-109

Electrical Power System Harmonics Elimination Using ETAP

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Received: 10/1/2022 Accepted: 5/2/2022

ABSTRACT

Because of the fast advancement in the creation of power electronics equipment such as automatic Machines, adjustable speed drives, personal computers and other non-linear loads which are the main sources of harmonics. Due to the presence of these nonlinear loads, it is necessary to reduce the level of harmonics created in the power networks. Hence, harmonic analysis of distribution networks is important. The analysis of power systems is an important part of power system engineering. Any electrical utility company's principal goal is to provide the best quality of power. The power system harmonics is one of the major reasons of poor power quality. Harmonics and harmonic analysis must be investigated in filters in order to minimize harmonic current and voltage. This paper aims to build a simulation model of nine bus ring system to evaluate characteristics of harmonics in different cases of study using Electrical Transient and Analysis Program (ETAP). Using ETAP harmonic distortion is analyzed and mitigation techniques are used represented by single tuned filters which should be installed for worst case and the best-case condition. And the simulation results of ETAP shows that some of THDv,i% results are within the limit value as per IEEE 519 -1992 standard.

Keywords:

ETAP; Non - Linear Loads; Single Tuned Filter; THD%; IEEE 519 -1992.

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1. INTRODUCTION

Ideally, an electrical supply should always show a perfectly sinusoidal voltage signal. However, utilities frequently find it difficult to maintain such desirable conditions for a variety of reasons. Waveform distortion, also known as harmonic distortion, is a word used to describe the deviation of voltage and current waveforms from sinusoidal [1].

Harmonics are periodic wave components with frequencies that are integer multiples of the fundamental power network frequency and may be represented using the Fourier series. Harmonics are typically produced as a by-product of power electronics-based loads. Non-linear loads or devices, such as personal computers, static power converters, uninterruptible power supplies, variable speed drives, cycloconverters, arc furnaces, fluorescent lights, saturated transformers, and so on, produce harmonics by consuming current in rapid short pulses rather than smooth sinusoidally. When harmonics are produced it is necessary to reduce it for better performance of the system [2][3][4]. For a signal whose fundamental frequency is f, the 2nd harmonic has a frequency 2f; the third harmonic has frequency of 3f, and so on. Signals that occur at frequencies of 2f, 4f, 6f, etc. are called even harmonics, as shown in fig. 1a; and at frequencies 3f, 5f, 7f etc. are called odd harmonics, As shown in fig. 1b.

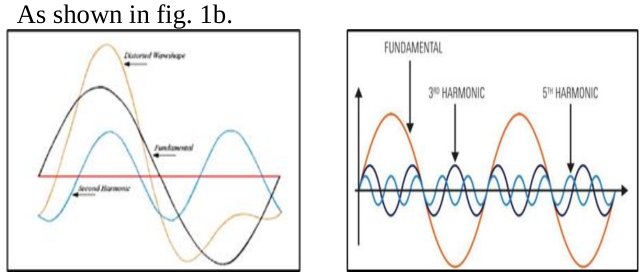

Fig. 1a Even harmonics. Fig. 1b Odd harmonics.

ETAP is a program that assists electrical engineers in the process of planning, modeling, operating, and optimizing power systems. Load flow analysis, short-circuit analysis, harmonic analysis, transient stability analysis, and other analyses can be performed on the designed project. By load flow analysis we can study the harmonics analysis. First of all we study the load flow analysis at the fundamental frequency. We may analyze the power factor at different buses in the electrical power system using load flow analysis, and then check the harmonics analysis and order of harmonic spectrum using harmonics analysis.[2][5]

The THD (Total Harmonic Distortion) value is the most important metric for harmonic analysis and measurement. The IEEE 519-2014 Standard is used as a standard for the detection of harmonic issues in the process industry.[7]

Much of the study has focused on the loads that create harmonics, how to construct a filter to remove harmonics, and so on. One of the most popular methods for removing harmonics is to use filters. Others used variable speed drives in the industrial power supply to remove harmonic current.[2][10]

In this paper, ETAP is being used to model a 9-bus 50Hz power network as shown in Fig. 2, perform harmonic mitigation and design a single tuned filter to mitigate the harmonics. The most common passive filters used in industrial are single tuned filters which creates low impedance path for the tuned frequency so that particular harmonic current will be diverted, thus, single tuned filters were used for the worst-case and the best-case scenario.

To examine the influence of harmonic current on the system, a general load was modeled as a harmonic source, and then a harmonic load flow analysis was done. Several sorts of harmonic manufacturers and models are included in the load harmonics library. The most appropriate type of harmonic model was chosen based on the THD indices. In this paper, load was modelled as a source of harmonics. From load harmonic library typical IEEE 6 pulse 1 model was identified as the worst typical IEEE model and IEEE 12 pulse 2 was identified as one of the best typical IEEE model because it has low THDv,i% values.

Filter were designed and placed on the buses that contain load which in this paper are bus (5, 6, 8) to mitigate the harmonics on these buses and to reduce the THDv,i% values for the 9-bus system. The ETAP simulation results reveal that some harmonic voltage and current are well within the limit value as per IEEE 519-1992 standard.

In addition to this introduction, this paper contains four other sections. Section 2 presents the harmonics filter. Harmonic mitigation using ETAP is explained in section 3. Harmonics filtering steps for typical IEEE 6pulse 1 model at the buses (5, 6, 8), at 5^{th} and 7^{th} order using ETAP are included in section 4. Section 5 includes I_{Sh}/I_L calculations.

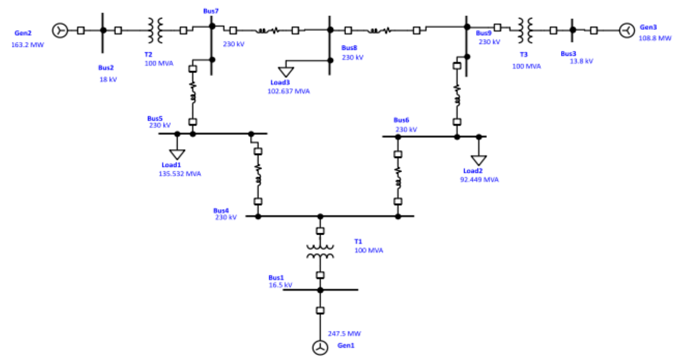

Fig. 2 Nine-bus system diagram.

2. HARMONICS FILTER

Equipment early failure and degradation, poor power factor, and resonance are all consequences of harmonics on a power system. Transformers, motors, cables, load interrupters, and power factor improvement capacitor banks are among the equipment impacted by harmonics. There are a variety of ways to minimize harmonics in a system, one of which is to use harmonic filters. Harmonics are reduced by creating a tuned filter for the most prevalent harmonic order.[7][8]

There are a variety of ways for reducing system harmonics, one of which is the use of filters. Filters are classified as passive, active, or hybrid. Passive filters are those that are made up entirely of passive components such as capacitors, inductors, and the like, and hence do not require any external power. These are the cheapest filters available, and they provide a low impedance path for undesirable harmonics.[8]

We used filters for:

1. Improve power factor.
2. Eliminate/ Reduce harmonics in voltage & current waveforms.
3. Combinations of the above [9].

One of the most prevalent approaches for reducing harmonic distortion in industries is to use passive filtering techniques that use single-tuned or band-pass filters. Single-tuned components that provide a low impedance path for harmonic currents at a certain frequency, or band-pass devices that filter harmonics over a specific frequency bandwidth, are examples of passive harmonic filters [1].

3. HARMONIC MITIGATION USING ETAP

The majority of loads in a power system are nonlinear, producing harmonic current or voltage. As a result, designing electrical components that decrease harmonics in power systems is essential. ETAP will examine some of the most advanced approaches, such as filters. Single tuned filters should be included in this project for the worst-case and the best-case situation at the buses that contain load. By entering the harmonic order and corresponding parameter value on the filter sizing page in ETAP, it is simple to eliminate the harmonic distortion of a certain harmonic order.

3.1 Single Tuned Filter design

Single tuned filters are designed to mitigate a single harmonic. These filters are basically used to mitigate lower order harmonics [8]. The inductor and capacitor in this filter are designed to mitigate a specific order of frequency by providing a low impedance path. In comparison to active filters, the design of a passive filter is fairly simple and cost-effective [11]. Single tuned filters, which have very low resistance at the tuning frequency, are the most common passive filters used in industry [1].

For the single tuned filter type, a filter sizing program is provided in the harmonic filter editor (as shown in fig. 3), allowing users to optimize filter parameters depending on various installation or operation conditions [12].

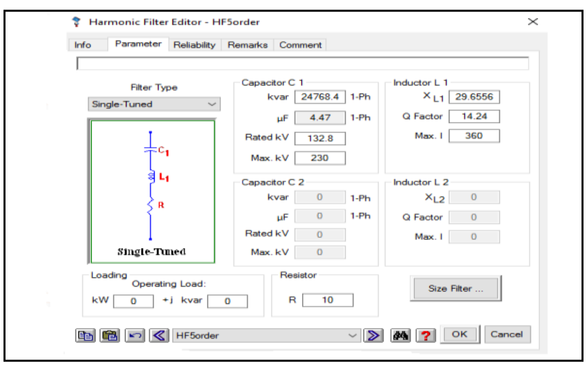

Fig. 3 Harmonic Filter Editor.

In ETAP filter sizing can be done for single tuned type after completing data entry on harmonic filter sizing page. Fig. 4 shows filter sizing window.

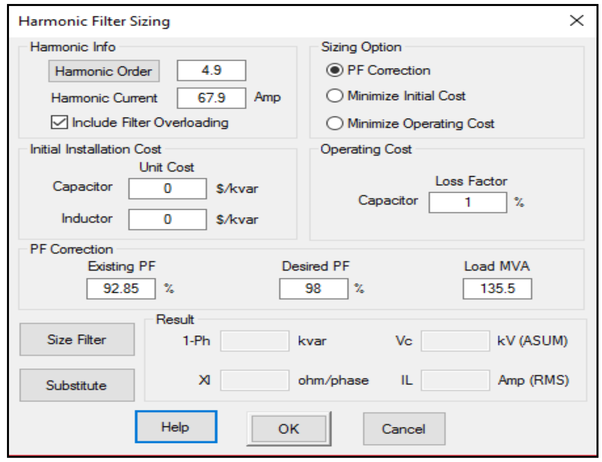

Fig. 4 Filter sizing window.

The harmonic order number must be specified by the user. A harmonic load flow analysis is performed for each harmonic order to determine the harmonic current that may be employed in filter sizing. Balanced load flow analysis on the power network must be used to determine the existing power factor and load MVA values that are used in the filter design. The parameters of the filter component are calculated and substituted to filter when you click the 'Size Filter' button.

4. HARMONICS FILTERING STEPS AT THE BUSES (5, 6, 8).

4.1 Harmonics Filtering Steps for Typical IEEE 6 Pulse 1 Model at The Buses (5, 6, 8), at 5TH And 7TH Order Using ETAP.

1- Set the load as a source of harmonics, and from load harmonic library we chose typical IEEE 6 pulse1 model.
2- Run load flow analysis to determine the MVA and the existing power factor at the desired buses.
3- In this paper the values of **MVA and PF** for the nonlinear loads at the buses (5, 6, 8) are:

a. On bus 5
135.5 MVA and 92.85% PF.

b. On bus 6
92.45 MVA and 94.87% PF.

c. On bus 8
102.6 MVA and 94.39% PF.

4- To determine the harmonic current run harmonic analysis → run harmonic load flow, then we choose the harmonic order from the harmonic slider. Table (1) shows the values of harmonic current at the buses (5, 6, 8) it is also shown in fig. 5.

Table (1) Harmonic current for the 5th and the 7th order.		
Bus NO.	**Harmonic order**	**Harmonic Current%**
5	**5th**	**67.9**
	7th	**20.5**
6	**5th**	**57.5**
	7th	**6.5**
8	**5th**	**35.2**
	7th	**20.3**

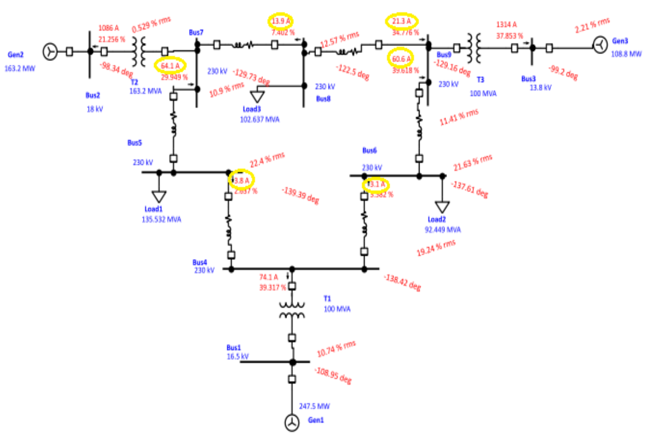

Fig. 5 Harmonic current value on the buses (5, 6, 8).

5- After placing all the values, the user press 'Size Filter' and then 'Substitute'. ETAP has the inbuilt function to compute the appropriate values for the capacitor and inductor as shown in fig. 6.

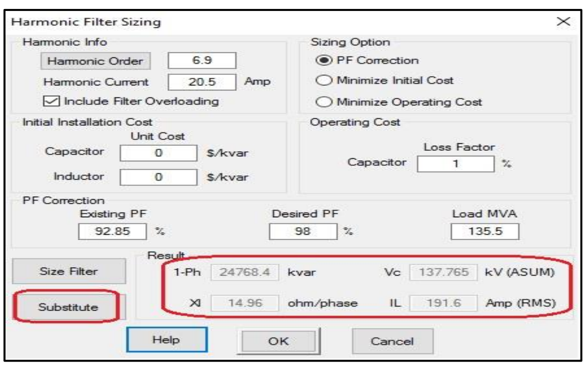

Fig. 6 Sizing harmonic filter (for the 7th order).

6- To complete the filter design, the value of quality factor of bus (5, 6, 8) should be calculated. Equations (1) and (2) are used to calculate the **quality factor Qf** at F=50 Hz. The value of inductance of nth harmonics order is:

$$L = \frac{1}{(2\pi F n)^2 \times C} \quad \dots\dots\dots (1)$$

The value of **quality factor Qf** for this filter is:

$$Q_f = \frac{1}{10} \times \sqrt{\frac{L}{C}} \quad \dots\dots\dots (2)$$

Table (2) shows the values of quality **factor** at bus (5, 6, 8) at 5th and 7th harmonic order:

Table (2) Quality factor values		
Bus no.	**h=5**	**h=7**
5	**14.24**	**10.17**
6	**31**	**22.07**
8	**24.8**	**17.73**

4.2 Harmonics Filtering Steps for Typical IEEE 12 Pulse 2 Model at The Buses (5, 6, 8), at 11th Order Using ETAP

In this project single tuned were used to mitigate the harmonics from the system, this filter must be designed to use it properly. Steps to design the single tuned filter are:

1- choose the load as a harmonic source, then from load harmonic library we chose typical IEEE 12 pulse2 model.

2- Run load flow analysis to determine the MVA and the existing power factor at the desired buses. In this project the values of MVA and PF for the non-linear loads at the buses (5, 6, 8) are:

1- On bus 5
135.5 MVA and 92.85 % PF.

2- On bus 8
102.6 MVA and 94.39% PF.

3-On bus 6
92.45 MVA and 94.87% PF.

The next step is the filter design, first we select the type of the filter which is single-tuned filter and then sizing it by insert the order of harmonic to be filtered, the harmonic current associated with it, existing power factor, desired power factor and the load MVA at that bus. Then we followed these steps to determine the harmonic current:

Run harmonic analysis ➡ run harmonic load flow, then we choose the harmonic order from the harmonic slider. In this model the order of harmonic starts from 11, 13, Etc. The harmonic current for order 11 of this model is shown in table (3).

Table(3) Harmonic current at H=11.	
Bus NO.	**Harmonic Current%**
5	**4.2**
8	**6.2**
6	**6.4**

The last step in the filter design is to find quality factor **Q_f**. Table (4) shows the value of **Q_f** of the at bus (5, 6, 8) for 12 pulse 2 model.

Table(4) Quality Factor	
Bus NO.	**Quality Factor Qf**
5	**6.47**
6	**14.04**
8	**11.28**

5. I_{Sh}/I_L CALCULATION

This paragraph presents the THDv,i% calculation of the system using ETAP, include total harmonic distortion (THDv%) which can be obtained from the buses and (THDi%) which can be obtained from the transmission lines and transformers after running "run harmonic load flow" with an indication to which of them had exceed the limits referring to the IEEE standards. Then we compared 6 pulse 1 model that has the highest THDv% values with 12 pulse 2 model which has lower THDv% values, first we should know the value of the short circuit current (I_{sh}) and the value of the load current (I_L). The steps to calculate the short circuit current are:

Click on short circuit icon ➡ fault the required buses (5, 6 ,8) ➡ run 3ϕ design duty. Fig. 7 shows I_{sh} calculation steps.

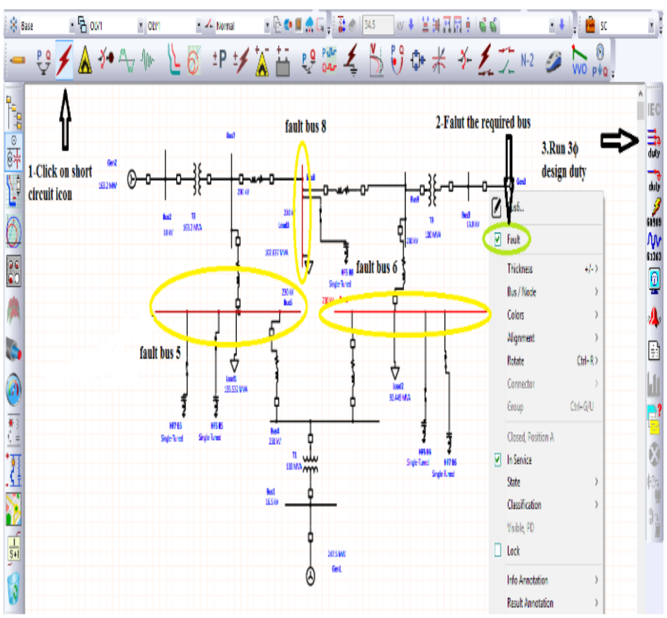

Fig. 7 Short circuit current calculation steps.

Table (5) shows the values of I_{sh}/I_L on bus (5, 6, 8). Table (6) show IEEE 519-1992 Voltage Harmonic Limits which shouldn't exceed, table (7) show IEEE 519-1992 current harmonic limits that shouldn't exceed. The load current and short circuit current are:

Table (5) Values of I_{sh}/I_L on bus (5, 6, 8)

Bus No.	I_{sh}	I_L	I_{sh}/I_L
5	3.049 KA	337.7A	9.028
6	2.911 KA	233.6A	12.46
8	4.208 KA	260.8A	16.13

Table (6) IEEE 519-1992 voltage harmonic limits.

Bus Voltage at PCC	Individual Voltage Distortion (%)	Total Voltage Distortion THD (%)
69 KV and below	3	5
69.001 kv through 161 KV	1.5	2.5
161.001 KV and above	1	1.5

In this paper the value of the bus voltage at PCC is 230 KV, thus, from table (6) the value of THDv% and THDi% should be 1 and 1.5 respectively.

Table (7) IEEE 519-1992 current harmonic limits (>161KV).

I_{sh}/I_L	<11	11≤h<17	17≤h<23	23≤h<35	35≤h	THDi%
< 50	2	1	0.75	0.3	0.15	2.5
≥ 50	3	1.5	1.15	0.45	0.22	3.75

From table (7) we notice that the value of I_{sh}/I_L in this project is less than 50 , thus, the value of THDi% should be approximately 2.5. After completing the previous steps, we then compared 6 pulse 1 and 12 pulse 2 model, to see the difference between them in terms of harmonics elimination.

Case A: Harmonic cancellation for typical IEEE 6 pulse1 model, before and after applying 5th and 7th order harmonic filters at the buses (5, 6) and 5th order harmonic filter at bus 8, and at transformer tap=±5% using ETAP.

Load was modeled as a harmonic source, thus, from load harmonics library we first chose 6 pulse 1 model, then we calculated THDv,i% before and after applying single tuned filter on the load buses (5, 6, 8). The values of RMS% voltages at transformer tap=0 have exceeded the allowable limits which is equal to 105%, thus, to get the allowable limit of the RMS% voltages, we set the transformer tap to ±5%.

Table (8) shows THDv% and RMS% voltage at. And table (9) shows THDi% values before and after applying filters at tap=±5%. Fig. 8 shows harmonic calculations THDv,i% and RMS% voltages before

applying filters for 6 pulse 1 model, and fig.9 shows harmonic analysis
plots for buses, transformers and transmission lines for typical IEEE 6 pulse 1 model before inserting filters. All this at transformer tap=±5%.

From table (8) notice that the 6th switch case has the lowest THDv %values but it didn't reach the IEEE 519-1992 harmonic limits and the RMS% voltages of this switch case have exceeded the maximum RMS% voltages limit for the system which is equal to 105%.

Table (8) THDv% and RMS% voltage values at Tap =±5% for h=5th&7th.

Model Type	Switch Case		Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9
Typical IEEE 6Pulse1	1) All Open	THD%	13.45	0.54	2.48	25.77	27.33	24.89	12.23	13.78	13.86
		RMS%	104.9	103	102.5	94.99	92.55	93.44	93.02	92.35	93.85
	2)S5 Closed	THD%	12.91	0.54	2.68	24.14	20.96	25.81	12.14	15.05	14.87
		RMS%	104.9	103	102.5	96.91	96.86	95.38	94.41	93.6	94.64
	3)S5 and S6 Closed	THD%	12.77	0.53	2.64	23.63	21.41	21.95	12.81	15.95	14.56
		RMS%	104.8	103	102.5	97.87	97.78	97.31	94.81	94.18	95.24
	4)S5, S6 and S8 Closed	THD%	10.45	0.471	2.25	19.45	11.67	20.42	10.43	13.81	12.26
		RMS%	104.6	102.5	102.5	97.28	96.54	97.53	95.64	96.51	95.87
	5)S5, S6, S8 and S5.1 Closed	THD%	10.44	0.522	2.37	18.48	10.49	19.85	11.48	14.26	2.37
		RMS%	104.6	108.9	107.6	101.2	105.4	102	102.2	102.5	107.6
	6)S5, S6, S8, S5.1 S6.1 Closed	THD%	9.79	0.529	2.28	16.81	10.45	13.07	11.69	14.24	12.44
		RMS%	104.5	115.4	114.7	104.1	109.7	107.2	108	108.5	107.2

Table (9) THDi% Values at Tap = ±5% for h=5th&7th.

Model Type	Switch Case	Line1	Line2	Line3	Line4	Line5	Line6	Transformer1	Transformer2	Transformer3
Typical IEEE 6Pulse 1	1) All Open	28.57	53.41	28.1	35.29	51.62	18.27	76.07	18.07	33.77
	2)S5 Closed	65.8	49.01	20.5	37.19	53.69	17.04	84.92	17.2	35.89
	3)S5 and S6 Closed	55.86	82.37	20.9	29.69	62.49	16.97	56.19	17.78	33.33
	4)S5, S6 and S8 Closed	71.38	90.7	15.18	28.15	35.46	18.16	30.77	11.11	25.7
	5)S5, S6, S8 and S5.1 Closed	23.88	53.46	17.2	34.75	25.62	22	11.66	12.86	28.12
	6)S5, S6, S8, S5.1, S6.1 Closed	15.32	21.17	21.63	31.66	33.08	22.19	14.3	14.3	27.36

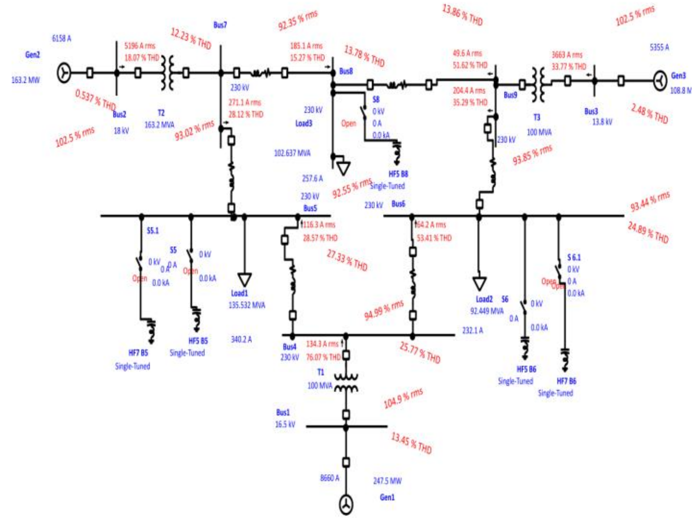

Fig. 8 Harmonic calculation (THDv,i) and RMS% voltages before applying filters at transformer tap=±5%.

Fig. 9 Harmonic analysis plots for buses, transformers and transmission lines for typical IEEE 6 pulse 1 model before inserting filter at tap=±5%.

Fig. 10 shows THDv,i% values and RMS% voltages after injecting the 5th and the 7th order harmonic filters on bus (5, 6) and Injecting 5th order filter on Bus 8 at transformer tap=±5%, also harmonic analysis plots for buses, transformers and transmission lines are shown in fig. 11.

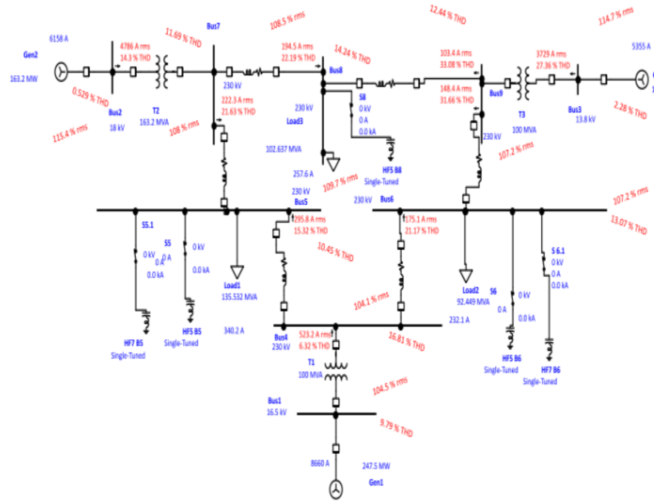

Fig. 10 THDv,i% values and RMS% voltages after injecting the 5th and the 7th order harmonic filters on bus (5, 6) and Injecting 5th order filter on Bus 8 at transformer tap=±5%.

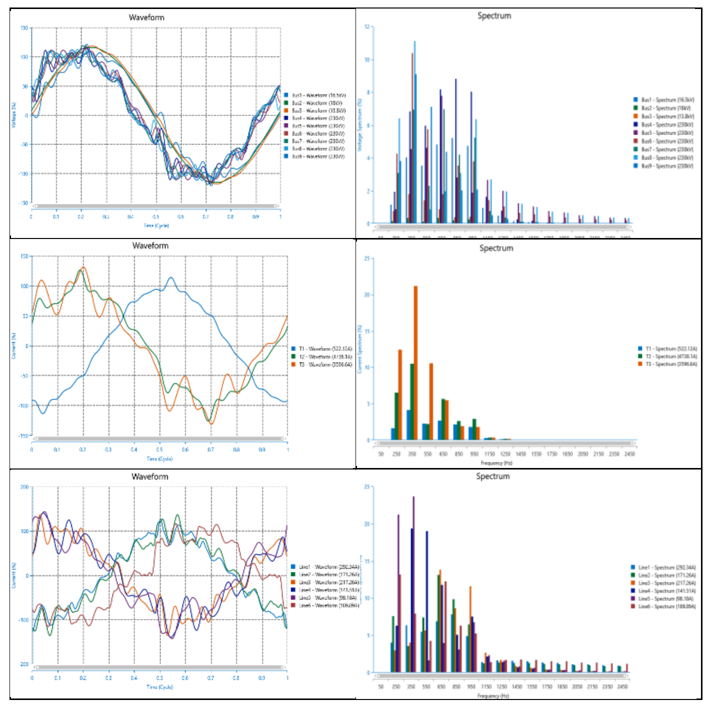

Fig. 11 Harmonic analysis plots for buses, transformers and transmission lines after injecting the 5th and the 7th order harmonic filters on bus (5, 6) and Injecting 5th order filter on Bus 8 at transformer tap=±5%.

Case B: Harmonic cancellation for typical IEEE 12 pulse2 model, before and after applying 11th and 13th order harmonic filters at the buses (5, 6, 8), and at transformer tap=±5% using ETAP

As we mentioned earlier, we set the transformer tap to 5% in order to get the allowable limit of the RMS% voltages which is equal to 105%.

Table (10) shows THDv% and RMS% voltages before and after applying harmonic filter on bus (5, 6, 8) at transformer tap equal to ±5, also we have THDi% values shown in table (11) at transformer tap= ±5% for typical IEEE 12 pulse 2 model.

Table (10) THDv% and RMS% voltages at Tap = ±5% for h=11&13.

Model Type	Switch Case		Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus 9
Typical IEEE 12Pulse2	1)All Open	THD%	3.78	0.099	1.35	7.25	7.12	3.12	2.37	4.06	7.56
		RMS%	104.1	102.5	102.5	92.23	89.5	90.72	92.35	91.56	93.23
	2)S5 Closed	THD%	3.59	0.228	0.699	6.74	6.24	5.38	5.15	3.09	3.88
		RMS%	104.1	102.5	102.5	94.19	94.4	92.3	93.7	92.48	93.61
	3)S5 and S6 Closed	THD%	5.44	0.212	1.22	10.11	7	7.5	4.79	3.26	6.74
		RMS%	104.2	102.5	102.5	95.38	95.17	94.85	93.97	92.89	94.32
	4)S5, S6 and S8 Closed	THD%	5.56	0.177	1.51	10.28	6.61	7.46	3.97	3.65	8.23
		RMS%	104.2	102.5	102.5	95.8	95.84	95.44	95.02	95.32	95.3
	5)S5, S6, S8 and S5.1 Closed	THD%	3.8	5.35	2.19	6.8	3.87	7.42	5.35	4.6	11.88
		RMS%	104.1	105.3	104.2	98.41	102.5	98.13	98.53	98.28	97.83
	6)S5, S6, S8, S5.1 S6.1 Closed	THD%	3.32	0.34	3.09	5.78	4.02	4.4	7.46	7.76	16.85
		RMS%	104.1	111.7	111.2	101.4	106.7	103.9	104.3	104.3	104.7
	7)S5, S6, S8, S5.1, S6.1, S8.1 Closed	THD%	3.44	0.178	1.91	5.73	3.92	4.33	3.97	4.77	10.46
		RMS%	104.1	126.5	125.1	106	114.7	111.5	117	118.6	116.2

Table (11) THDi% Values at Tap = ±5% for h=11&13.

Model Type	Switch Case	Line1	Line2	Line3	Line4	Line5	Line6	T 1	T 2	T 3
Typical IEEE 12Pulse2	1)All Open	13.24	31	4.93	11.1	4.54	17.38	11.86	1.85	9.58
	2)S5 Closed	32.78	21.39	7.43	8.74	14.56	8.47	14.65	3.85	5.46
	3)S5 and S6 Closed	42.84	55.11	7.38	13.9	16.03	8.37	17.4	3.43	9.19
	4)S5, S4 and S8 Closed	38	50.73	6.74	15.5	10.39	6.79	14.09	2.98	10.99
	5)S5, S6, S8 and S5.1 Closed	11	17.93	5.67	23.3	7.6	7.7	4.55	4.06	15.07
	6)S5, S6, S8, S5.1 and S6.1 Closed	6.51	9.1	7.97	31.2	15.11	7.97	2.36	7.03	24.33
	7)S5, S6, S8, S5.1, S6.1 and S8.1 Closed	4.17	5	11.24	40.4	3.84	5.48	1.48	4.52	18.47

From table (10) we notice that form switch case 1 to switch case 5 the RMS% voltages stayed within the limits which is 105% and after changing the transformer tap to ±5%. The switch case 7 has the lowest THDv % but the RMS% voltages exceed the limits. These results were calculated as a final step to inject the harmonic filter, because if we inject more filters, the RMS% voltages will exceed the allowable limit (105%).

Fig. 12 shows harmonic analysis results THDv,i% and the RMS% voltages after inserting a 11th and 13th order harmonic filters on bus (5, 6, 8), and fig. 13 shows harmonic analysis plots for buses, transmission lines and transformers after inserting a 11th and 13th order harmonic filters on bus (5, 6, 8) for typical IEEE 12 pulse 2 model and at transformer tap=±5%.

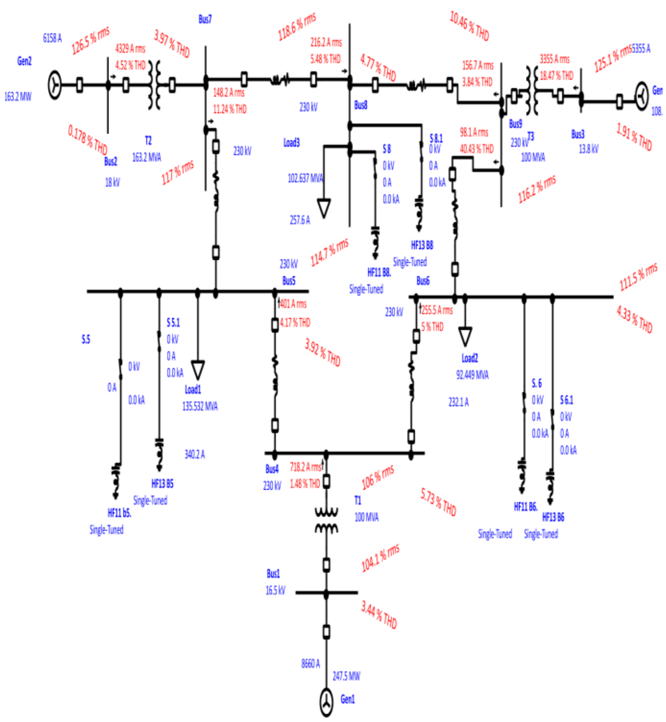

Fig. 12 Harmonic analysis results THDv,i% and RMS% voltages after inserting a 11th and 13th order harmonic filters on bus (5, 6, 8) at tap=±5%.

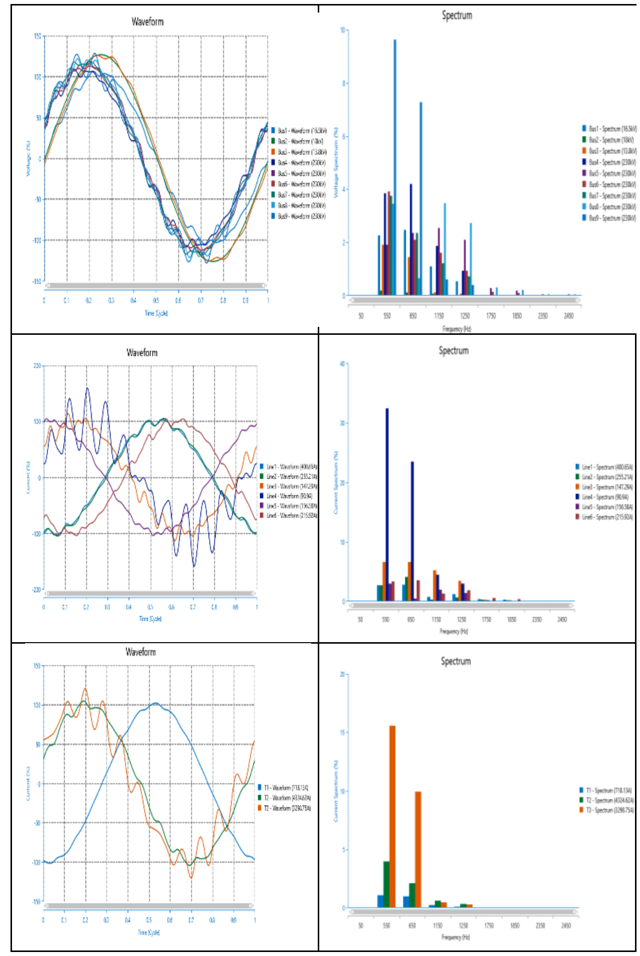

Fig.12 Harmonic analysis plots for buses, transmission lines and transformers after inserting a 11th and 13th order harmonic filters for typical IEEE 12 pulse 2 model at tap=±5%.

6. CONCLUSION

To study power system harmonics, a simple power network with nine busbars was simulated. Harmonic load flow study was performed to identify the effect of harmonic current for a power network. On running harmonic load flow study, harmonic distortion was seen on the one-line diagram and plotted curve. Mitigation technique using single tuned filter was analyzed and performed to eliminate harmonic distortion created by the modelled harmonic sources. The results show that:

1. The THDv,i% were reduced but it didn't reach the IEEE 519-1992 standard.
2. The RMS% voltages at some points have exceed the allowable limit which is equal to 105%, although the tap value was changed to ±5%.

However, these results were considered as a final step to inject the harmonic filter, because the more filters we inject, the higher RMS% voltages we got. if we inject more filters, the RMS% voltages value will increase. The ETAP load flow analysis result was compared with the result of the load flow analysis in MATLAB, and comparison shows that the ETAP load flow analysis results were more accurate than MATLAB results.

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ازالة توافقيات نظام طاقة كهربائية بأستخدام ETAP

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الملخص

بسبب التقدم السريع في إنشاء معدات إلكترونيات الطاقة مثل الآلات الأوتوماتيكية ومحركات السرعة القابلة للتعديل وأجهزة الكمبيوتر الشخصية والأحمال غير الخطية الأخرى التي تعد المصادر الرئيسية للتوافقيات. نظرًا لوجود هذه الأحمال غير الخطية ، من الضروري تقليل مستوى التوافقيات التي تم إنشاؤها في شبكات الطاقة. ومن ثم ، فإن التحليل التوافقي لشبكات التوزيع مهم. يعد تحليل أنظمة الطاقة جزءًا مهمًا من هندسة أنظمة الطاقة. الهدف الرئيسي لأي شركة خدمات كهربائية هو توفير أفضل جودة للطاقة. تعد توافقيات نظام الطاقة أحد الأسباب الرئيسية لضعف جودة الطاقة. يجب فحص التوافقيات وتحليلها ومن ثم اختيار المرشح المناسب لتقليل توافقيات الجهد والتيار. يهدف هذا البحث إلى بناء نموذج محاكاة مكون من تسعة قضبان عمومية لتقييم خصائص التوافقيات في حالات الدراسة المختلفة باستخدام برنامج التحليل الكهربائي العابر (ETAP)، والذي يعتبر من أفضل الأدوات لدراسة التوافقيات في نظام الطاقة ، وبالتالي ، يتم تحليل التشوه التوافقي في ETAP ويتم استخدام تقنيات التخفيف المتمثلة بمرشحات احادية الرنين والتي يجب تركيبها في أسوأ وأفضل حالة. وتظهر نتائج محاكاة ETAP أن بعض قيم THDv ,i% تقع ضمن القيمة الحدية فيما يتعلق بمعيار IEEE 519-1992.

الكلمات الدالة:

ETAP، ألاحمال الغير خطية، مرشح احادي الرنين، معيار *IEEE 519 -1992 ,THD%* عامل التشوه الكلي.