MEASUREMENT AND ANALYSIS OF BASE TRANSCEIVER STATIONS POWER QUALITY PARAMETERS AND ASSESSMENT OF ITS UNFAVOURABLE EFFECTS ON IRAN DISTRIBUTION SYSTEMS

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ABSTRACT

The increasing use of power electronic loads in industry and consumers results in injection of the considerable amount of current harmonics to the distribution system. Current harmonics of nonlinear loads may be generating harmonic voltage drops due to the distribution system impedance. These harmonics cause unwanted effects like transformer overheating, over currents on neutral conductors, communications failures, errors in monitoring equipment and disorder in operation of other devices. One of the most important nonlinear loads is rectifier. Depending on the congestion of conversations, Base Transceiver Station (BTS) for mobile communication includes several single phase rectifiers to feed batteries and amplifiers with over five kilowatt rated power in Iran. There are more than 30000 BTS in Iran which inject large amount of current harmonics to distribution systems. In each BTS, there are various types of rectifiers which each of them has different circuit topology and injects different harmonics.

In this paper, in order to comprehensive study, the stations with different types of rectifiers, various congestion of conversations and different distances from supply system were selected to measurement and analyze. Then, voltage, current, active power and power quality parameters of selected stations were measured using ION power analyzer devices and data were recorded. The results of measurement and analyze show that the power quality parameters in these stations are not in standard range and will be harmful to distribution systems. Depending on the harmonic spectrums of current in these stations, several methods are proposed to improve power quality parameters such as: using of suitable transformer in primary side, embedding and tuning passive filters to eliminate specific harmonics and using of renewable energy systems as off grid. Besides, one passive filter has been designed and implemented that reduces total harmonic distortion of injection current considerable.

INTRODUCTION

More and more nonlinear loads have been used in power systems with the development of power-electronic technology, thus injecting a lot of harmonic currents into power system. Many studies have shown that the harmonics may produce adverse effects on power systems, communication systems, and various apparatus.
The current of non-linear loads is non-sinusoidal while the applied voltage is sinusoidal. Voltage distortion is made by the pass of the distortion current from the series and linear network impedance. Harmonic currents which pass the impedance of the system cause voltage drop in each harmonic [1]. On the other hand, harmonic currents cause additional losses in the network and also cause the overload, temperature increase, heat stress for the transformers and that leads to the reduction in the capacity of trances. In order to limit the amount of harmonics in distribution network some standards have been established and depending on them allowed limitation for the amount of harmonics is set. IEC1000-3 and IEEE-519-1992 are proper examples in this context [2].
According to the problems that harmonics cause in the electrical networks, it is essential to use the instruments which reduce or eliminate them. For this purpose, some techniques in power system are recommended and the most common ones are the active or passive filters [3]. Not only do these filters eliminate the harmonic and follow the harmonic standards especially the standard IEEE-519 appointed on Total Harmonic Distortion (THD) of the loads connected to the network, it compensates the reactive power [4]. Although passive filters have some problems such as the creation of series and parallel fluctuations with power network and also changing the specifications of the filter's elements over time, they are used more than active filters due to their low price [5].
Shunt passive filters are the most utilized method for harmonic mitigation because it is low cost and also regulate the load voltage [6]. They present low shunt impedance to the desired range of frequencies, therefore they divert harmonic currents through a low impedance shunt path with very little flowing back into the system, but they are dependent to the source impedance [6]. Series passive filter presents high series impedance to the desired range of frequencies, thus the harmonic currents are blocked [7]. One of the disadvantages of series filter is high cost, therefor the technical and economic methods used to eliminate harmonics in Series passive filters. In several papers different structures of passive filters are suggested and many studies have been done involving optimal passive filter design depending on the designer concerns [8-9]. Several hybrid passive filter (HPF) configurations for harmonic compensation and other objectives are presented in papers [6]. Insensitivity to source-impedance variations, removing the series / parallel resonance that may occur, is the special features

of the presented HPF system.
The mobile communication stations can be mentioned as the non-linear loads. The mobile communication stations are used in urban and rural areas to eliminate the network traffic and provide radio coverage and it is composed of at least the MTN or MCI cells to lower the density of antenna. But some congested stations may have three cells, MTN, MCI and Rightel. Several power supplies (rectifier) suitable for the conversation density of the station are used to produce direct voltage which supplies batteries and amplifiers in the station. Depending on the type of the load of the mobile communication stations, it is predicted that the current that consumers get is infected with harmonic.

In this study, power quality measurements are done in 12 BTS sites by the ION devices. After gathering the information, relevant to the instructions of the standard IEEE-519, indicators of each measurement are compared with the allowed limitation. The results show that some of the indicators are inside and some of them are outside the allowed limitation. Also the hybrid passive filter is designed for one of the stations which have unsuitable power quality condition to improve harmonic orders and total harmonic distortion.

BASE TRANSCEIVER STATIONS (BTS)

In the mobile phone network, the first part which is directly in relation with the mobile phone is the antenna BTS. These BTSs are installed in roads and in the areas with weak signals to provide radio coverage and eliminate the network traffic. These antennas are made from cells which have 3 sectors and each sector covers 120 degrees and totally they cover 360 degrees as shown in Figure 1.

Fig.1. The sectors of BTS antennas

Each sector can be independently installed to cover a special position. In the installation of BTS network, the most important point is the density and the number of subscribers. In this way, the intended area depending on the subscriber's density is divided to large and small hexagons and then an antenna is considered for each part. For example a site located in the downtown covers more subscribers than a site located in the road where a few people cross in an hour. Then these cells are bigger in the border city than downtown. Therefore in some regions the distance between stations can be 1000m or less than that and even it is possible that two sites be installed in the same place on the same mast but in the routes they may be 40km far from each other.
In fact, the BTS is a receiver-sender of the waves and it leads the waves to the amplifier to do some processes on them. For example getting the waves which have been sent from the transmitter and have passed a long way and have become weak is the work of the receiver antenna. The antenna gets these weak waves and sends to the amplifier of the device in order to reinforce them and become like a photo or an audio but the BTS antenna does both of these duties at the same time. In fact, it functions as a receiver in one frequency range and the sender in the other.
The main equipments of the BTS site are the antenna and its departments, DC-DC converter, DC-AC inverter, fans, coolers, radio and lighting system. Figure 2 indicates an overview of the power supply used in the BTS site and it contains filter, rectifier diode, boost DC-DC converter and high frequency transformer. According to the Fig.2 and the existence of the power electronic converters in the structure of power supplies in one BTS site, mobile communication stations depending on the type of the used load, are the consumer of the harmonic generator. Commonly, three types of power supply are used in IRAN mobile network such as: 1-Huawy Charger 2-Nian Electronic Charger 3-PSP Charger.

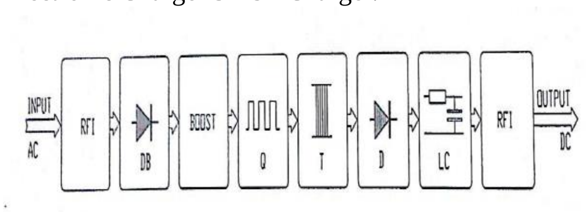
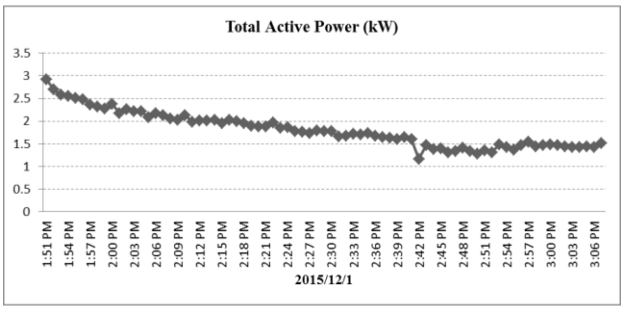


Fig.2. Power supply circuit applied in BTS cites

MEASUREMENT RESULTS

As mentioned, The ION power analyser is applied to measure voltage, current, active power and power quality parameters of the 12 selected stations. Because of the page limitation of paper, the summary results for one of the selected BTS sides in East Azarbaijan-Malekan are presented in this section. The type of power supply is Nian Electronic Charger and the short-circuit ratio is calculated as 27. Fig.3 shows Total active and reactive power for this BTS station.



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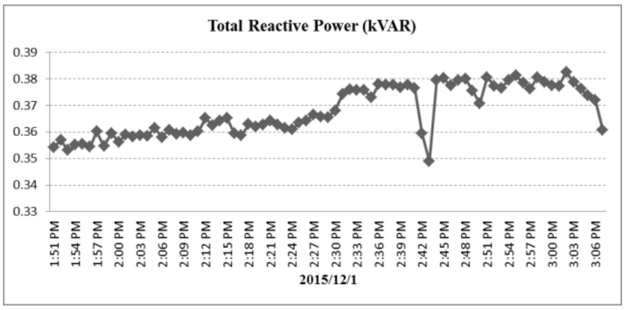
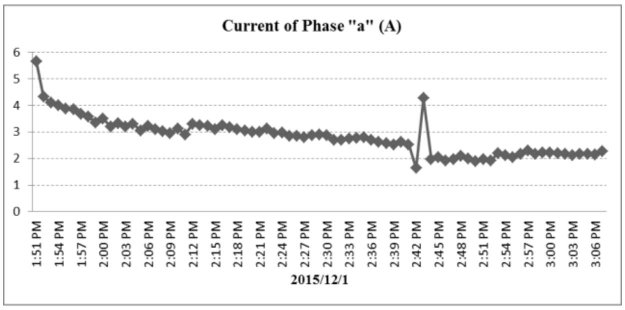


(b)

Fig.3. The measured active and reactive power in Malekan BTS station

The measured current of phase (a), 3rd, 5rd current harmonic and THD of phase (a) current are shown in Fig.4. The other harmonic orders are low and neglectable. It is obvious that the 3rd and 5rd harmonic orders are higher than IEEE-519 standard and must be compensated.



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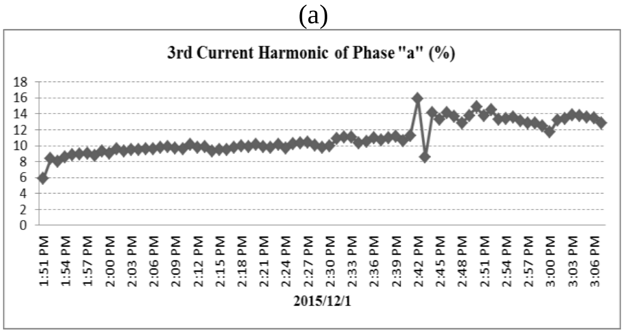

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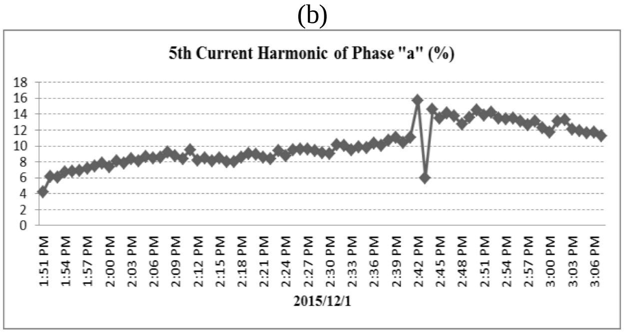

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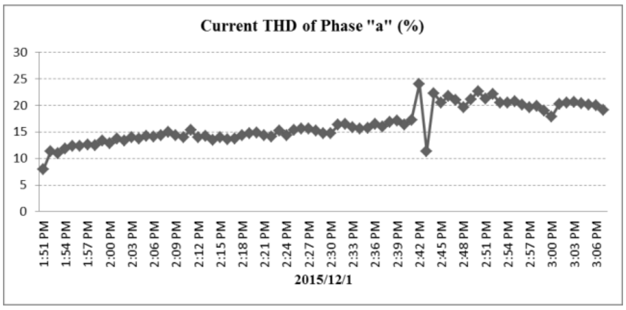
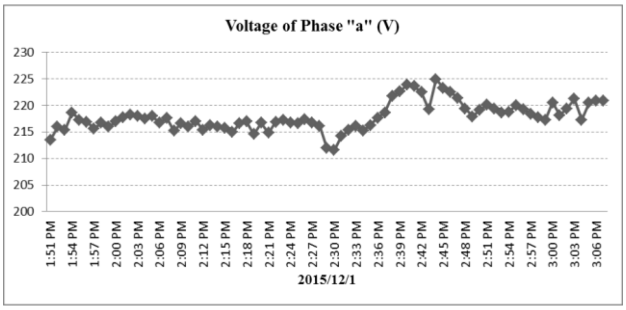


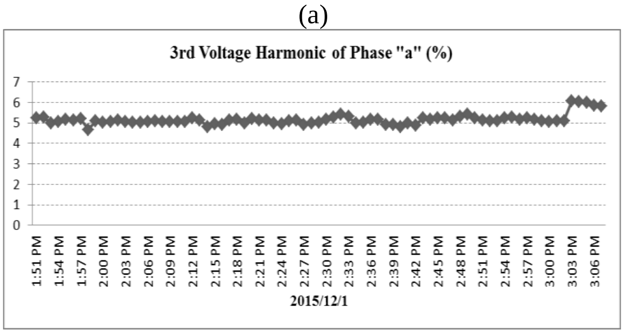
(d)

Fig.4. The measured current of phase (a), harmonic orders and THD

The measured voltage of phase (a), 3rd, 5rd voltage harmonic and THD of phase (a) voltage are shown in Fig.5. The other harmonic orders are low and neglectable. According to IEEE-519 standard, the voltage quality is not suitable.



(a)



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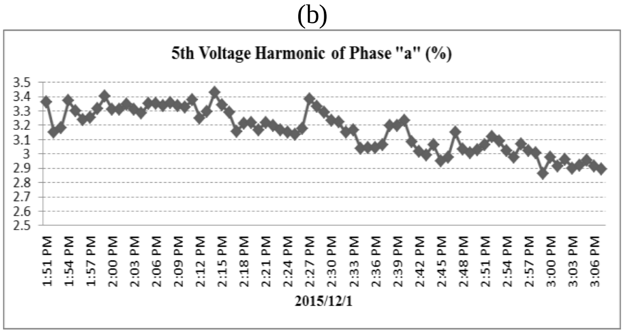

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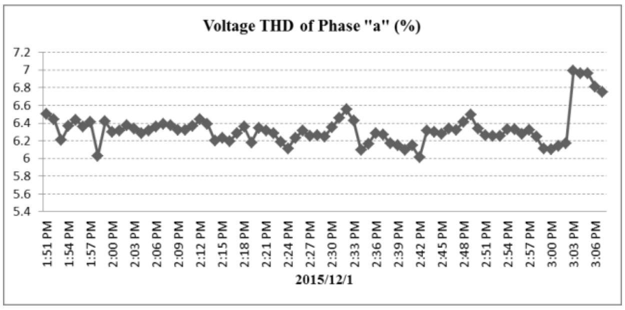
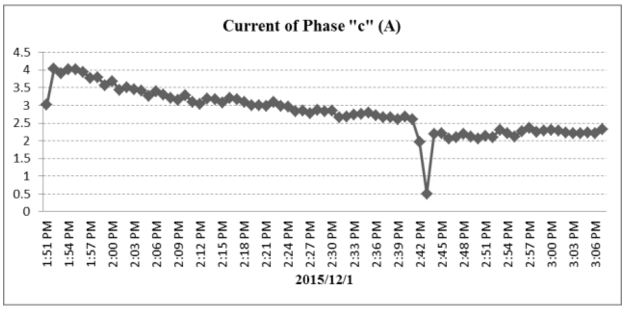


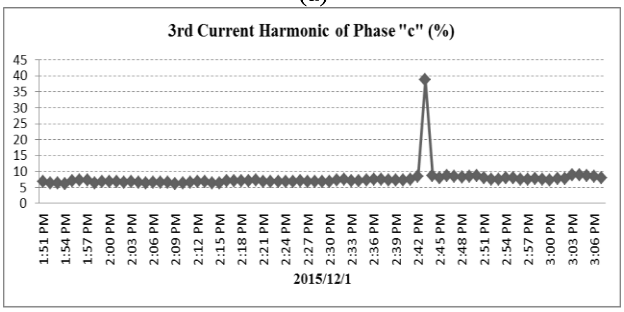
(d)

Fig.5. The measured voltage of phase (a), harmonic orders and THD

Fig.5 confirms that voltage THD, 3rd, 5rd harmonics are higher than standard range. The voltage of phase (b) , (c) are similar to this voltage with a few difference which because of page limitation do not shown in this paper. Also the THD and harmonics percent of the phase (b) current are in standard range (less than 7%) and do not shown in this paper [4]. Similar to phase (a), 3rd, 5rd harmonic orders and THD of phase (c) current are higher than IEEE-519 standard and must be compensated which illustrated in Fig.6.



(a)



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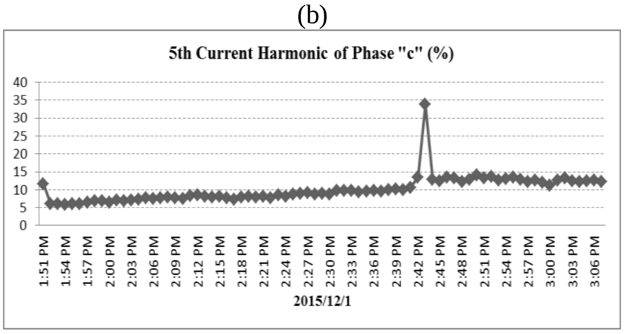

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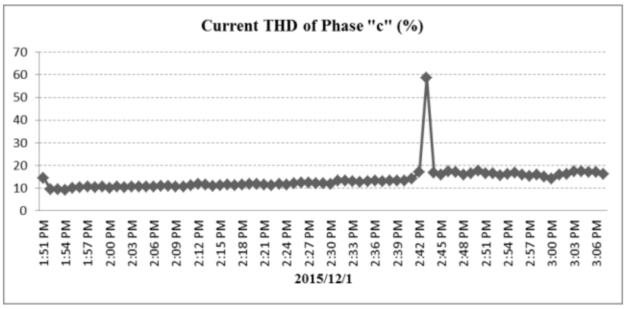

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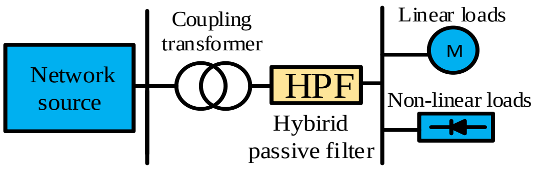
Fig.6. The measured current of phase (c), harmonic orders and THD

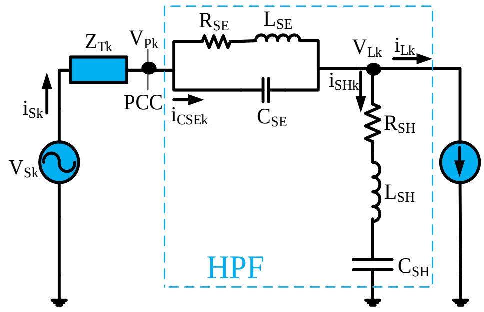
METHODS OF ELIMINATING OR REDUCING CURRENT HARMONICS

In this study, the standard IEEE-519 is applied as the reference allowed limitation for the harmonics. According to this standard, the allowed limitation of the harmonics are depended on the short-circuit ratio defined as the ratio between the short-circuit current and the fundamental load current (I_{sc}/I_L). When this ratio is high, the grid is strength and the allowed limitation of the harmonics is higher. In the weak grids, active and passive filters are the common methods to eliminate or reduce current harmonics but as mentioned, passive filters are used more than active filters due to their low price.

In this paper, an optimum hybrid passive filter (HPF) design is proposed for current harmonics compensation of the BTS stations. This configuration is composed from a shunt passive filter and a series passive filter in order to overcome the shortage of the shunt and series passive filters. This structure provides harmonic compensation over a wide spectrum under varying nonlinear loads and it is Independent from source impedance. The Teaching–learning-based optimization algorithm (TLBO) for the first time is used to optimize the filter parameters design under multi constraints and it shows excellent performance to perform this work. Fig. 7(a) shows the single line diagram of the studied distribution system. Also, a circuit of the presented hybrid passive filter is demonstrated in Fig. 7(b). The presented configuration is a suitable structure for preventing the parallel and the series resonances that may occur with the utility and loads at the special harmonic frequencies. Moreover, the series filter acts as an isolator between the power system and the loads. This filter acts independently from source impedance.



(a)



(b)

Fig.7. (a): Single line diagram of the studied distribution system (b): Equivalent circuit of the hybrid passive filter.

Maintaining the total current harmonic distortion and total voltage distortion at the PCC between the supplier and the customer in acceptable ranges are the main constraints in filter designing. According to IEEE 519–1992, THD for the voltage level up to 69 kV is limited to 5.0% and for each individual harmonic voltage is limited to 3%. THD of the current should be limited to a standard percentage according to the short-circuit ratio [2]. As mentioned, the THD and harmonics percent of the phase (b) current in the studied BTS station are in standard range (less than 7%). So the passive filter is designed and implemented for phase (a) and (c). The achieved parameters for passive filter from Teaching–learning-based optimization algorithm (TLBO) are listed in Table 1.

Table 1. The designed parameters of HPF by the TLBO optimization for a BTS station.

Parameters	L_{SE} (mH)	C_{SE} (µF)	R_{SE} (Ω)	L_{SH} (mH)	C_{SH} (µF)	R_{SH} (Ω)
Values	12	50	0.2	6.5	100	0.2

Table 2 and Table 3 illustrate harmonic spectrum of the phase (a), (b) currents before and after filter applying, respectively.

It is obvious that, by applying the designed HPF, the 3rd, 5rd and THD are improved.

Table2. Harmonic Spectrum (%) before filter applying

HD	Voltage			Current		
	a	b	c	a	b	c
2	0.1	0.1	0.1	0.3	0.2	0.3
3	6.1	6.7	5.9	15.9	5.7	8.9
5	3.4	2.6	2.5	15.7	5.1	14.02
7	0.9	1.2	1.3	1.2	0.9	1.3
9	0.7	0.7	0.5	0.8	0.7	1.1
THD	7	7.3	6.6	24	9.5	17.2

Table3. Harmonic Spectrum (%) after filter applying

HD	Voltage			Current		
	a	b	c	a	b	c
2	0.05	0.1	0.01	0.15	0.2	0.2
3	1.8	6.7	1.5	8.5	5.7	7.6
5	0.3	2.6	0.3	2.5	5.1	1.8
7	1.2	1.2	1.2	0.9	0.9	1
9	2	0.7	2.3	1.1	0.7	1.1
THD	7	7.3	6.6	24	9.5	17.2

CONCLUSION

The BTS stations are mentioned as the non-linear loads and the power quality parameters in these stations are not in standard range and will be harmful to distribution systems. In this paper, the summary results for one of the selected BTS sides are presented and also the hybrid passive filter has been designed to improve power quality of this station.

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