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EDITORIAL PREFACE

This is the *Fourth* Issue of Volume *Six* for International Journal of Engineering (IJE). The Journal is published bi-monthly, with papers being peer reviewed to high international standards. The International Journal of Engineering is not limited to a specific aspect of engineering but it is devoted to the publication of high quality papers on all division of engineering in general. IJE intends to disseminate knowledge in the various disciplines of the engineering field from theoretical, practical and analytical research to physical implications and theoretical or quantitative discussion intended for academic and industrial progress. In order to position IJE as one of the good journal on engineering sciences, a group of highly valuable scholars are serving on the editorial board. The International Editorial Board ensures that significant developments in engineering from around the world are reflected in the Journal. Some important topics covers by journal are nuclear engineering, mechanical engineering, computer engineering, electrical engineering, civil & structural engineering etc.

The initial efforts helped to shape the editorial policy and to sharpen the focus of the journal. Started with Volume 6, 2012, IJE appears with more focused issues. Besides normal publications, IJE intend to organized special issues on more focused topics. Each special issue will have a designated editor (editors) – either member of the editorial board or another recognized specialist in the respective field.

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Enhanced Direct Torque Control for Doubly Fed Induction Machine by Active Learning Method Using Indirect Matrix Converter

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Abstract

The term Direct Torque Control (DTC) originally is referred to a strategy which provides good transient and steady-state performance but it has also some negative aspects, such as non accuracy of flux, torque estimator, torque and flux ripple caused by non-optimality of switching and imprecision in motor model which are known as an inherent characteristic of DTC. This paper explores reducing of flux and torque ripple with using trial and error actively as a method called Active Learning Method (ALM) in DTC for Doubly Fed Induction Machine (DFIM) which are the motors or generators having twist on both stator and rotor subsequence power is transferred between shaft and system. DFIM is linked to the grid within the stator and the rotor is fed by an Indirect Matrix Converter (IMC). The function of IMC is similar to the direct one, although it has the line and load bridges separated. We analysis the usage of four-step commutation in rectifier stage of IMC to achieve the object of the losses' reduction which are caused by snubber circuit. ALM adopts itself with torque and flux estimators and estimates the outputs with regards to the errors in torque and flux estimation by repetition therefore achieves the object of omitting inaccuracies in control system hence confirming the effectiveness. Another concept in ALM called Ink Drop Spread (IDS) handles different modeling target to predict on the data consequensing a behavior curve in DTC. According to the simulation results, it is proved that a significant torque and stator flux ripple reduction are obtained.

Keywords: Active Learning Method; Direct Torque Control; Doubly Fed Induction Machine; Indirect Matrix Converter.

1. INTRODUCTION

The conventional energy sources are limit and have pollution for the environment, so more attention and interest have been paid to the utilization of renewable energy sources such as wind energy, fuel cell and solar energy etc. Among them wind energy is the fastest growing and most promising renewable energy source due to economically viable [1].

In the field of wind energy generation systems, the wind turbine development shows a tendency to increase the generation power level. According to the variation wind speed, Doubly Fed Induction Machine (DFIM) is a common solution for variable speed wind turbines [2].

Often, the wind energy generation demands good torque dynamic performance as well [2]. Among all methods of torque control developed for the induction machine, the most widely used technique may be classified within the Field Oriented Control (FOC) techniques and the direct control techniques [2]. It seems to be accepted that the direct control techniques first introduced such as Direct Torque Control (DTC) [3] and Direct Self Control (DSC) [4] achieve better steady-state and transient torque control conditions rather than FOC techniques [5],[2].

Direct Torque Control (DTC) accompanies by some problems such as non accuracy of flux, torque estimator, torque and flux ripple caused by non-optimality of switching and imprecision in motor model which are all the inherent characteristics of DTC. To overcome these difficulties lots of papers have been published on solving DTC drawbacks. Some of these papers fuzzified the DTC system inputs and improve its characteristics [6],[7], some else tried to improve the torque and flux estimators [8]-[10].

Active Learning Method (ALM) is a powerful recursive fuzzy modeling without computational complexity. ALM has been proposed as a new approach to soft computing. The concept of the ALM is based on the hypothesis that humans interpret information in the form of pattern-like images rather than in numerical or logical forms. The ALM is modeled algorithmically on the intelligent information-handling processes of the human brain, and it is characterized by computing on the basis of intuitive pattern information [10]-[13].

In the Active Learning Method to model the information, a method called as Ink Drop Spread (IDS) is used. The IDS method is able to deal with various modeling targets, ranging from logic operations to complex nonlinear systems [10]. The IDS method possesses stable fast convergence, and its modeling process, which is based on computing that uses pattern information instead of complex formulas, is simple and efficient [10],[14].

Matrix converters (MCs) have been studied widely since their principle was introduced in 1970[20]. A MC is an AC-AC converter, with m×n bidirectional switch, which connects an m-phase voltage source to an n-phase load . The matrix converter Compared with the conventional AC/DC/AC converter, has some merits such as : eliminating bulky DC link capacitor in it, straightforward Four-quadrant operation, also by controlling the switching devices appropriately, both output voltage and input current are sinusoidal with only harmonics around or above switching frequency [21].

Matrix-converter topologies can be divided into two types, one of them is direct matrix converters (DMC) and another one is indirect matrix converters (IMC) which consists of separated line and load bridges as presented in section [22].

Commutation problem of DMC is reduced considerably by utilize specific current commutation methods. Typically two types of commutations methods have been proposed which don’t require snubber circuits for a PWM rectifier of AC-to-AC converters without DC link components. The first method is named rectifier zero current commutation and the second is named rectifier four-step commutation. In these methods, although the losses in snubber circuits and the switching losses in the PWM rectifier can be reduced but a complicated control circuit must be added to synchronize the switching of both the PWM rectifier and the PWM inverter [22].

This research used ALM for DFIM to overcome the problems that were presented to DTC. ALM can adapt itself with torque and flux estimators and estimate the outputs regards to the errors in torque and flux estimations. Also proposed method avoids mathematical complexities of fuzzy like methods so it is faster than conventional methods [10],[14]. From another side for feeding DFIM’s rotor indirect matrix converter is used. The benefit of four-step commutation is analyzed in rectifier stage of IMC to achieve the object of the losses’ reduction which are caused by snubber circuit.

2. DIRECT TORQUE ONTROL PRINIPLE

Fig.1 shows the schematic of Direct Torque Control of DFIM. Stator winding of induction machine is connected directly to the grid and the rotor is fed by converter that is also connected to the grid. The main goal of the DTC is directly control the rotor flux and the electromagnetic torque of the DFIM with Choosing the best voltage vector.

As shown in fig.2, the position of the rotor flux is divided into six sectors. There are also 8 voltage vectors which-correspond to possible inverter states. These vectors are shown in fig.2. There are also six active vectors $V_1 - V_6$ and two zero vectors V_0, V_7.The torque rotor flux equation of doubly fed induction machine is as follows:

$$T_{em} = \frac{3}{2} p \frac{L_h}{\sigma L_s L_r} |\Psi_r||\Psi_s| \sin □ \tag{1}$$

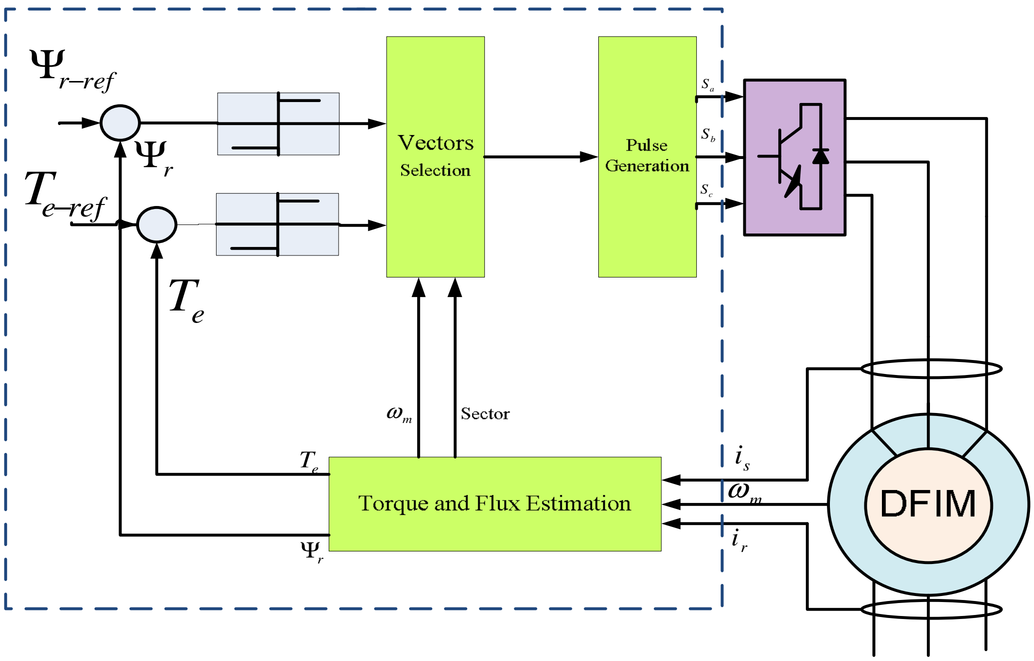

FIGURE 1: The diagram of the DFIM direct torque control system

Where $\sigma = 1 - \frac{L_h{}^2}{L_s L_r}$ is the leakage coefficient. L_s and L_r are the stator and rotor inductance, L_h is mutual inductance, R_r is rotor resistance and □ is phase angle difference between Ψ_r and Ψ_s. As the stator winding of DFIM is connected to power grid, by ignoring the voltage drop of stator winding resistance and the fluctuation of supply voltage, one can appropriately consider the magnitude of the stator flux to be constant and rotate at synchronous speed [15]. Therefore, according to equation (1), we know that the torque control of wound rotor doubly-fed machines can be realized through adjusting the rotor flux vector. Furthermore, in the case that the rotor flux $\overline{\psi_r}$ has a circular trajectory, T becomes the function of phase angle θ .T increases as θ increases. Conversely, T decreases as θ decreases. Therefore, the control of the torque/speed can be realized through adjusting the phase angle θ .

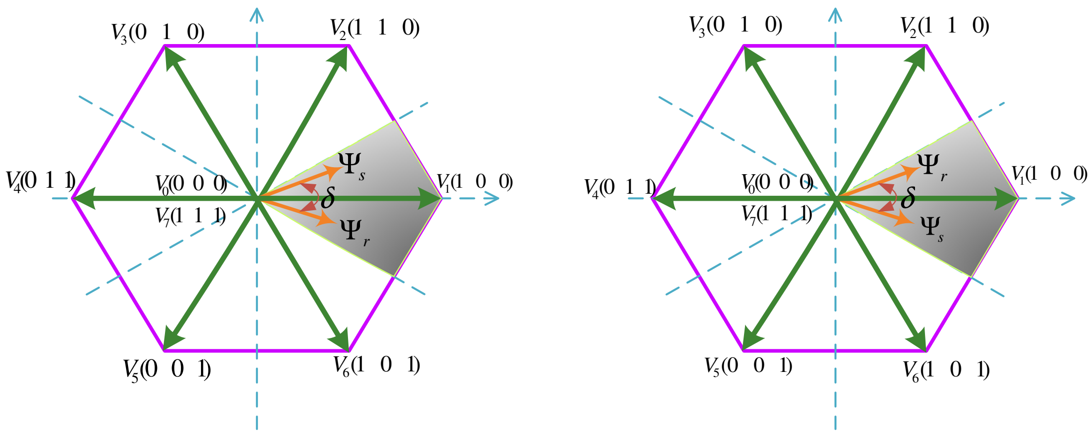

FIGURE 2: Flux space vectors in the rotor reference frame, in motor and generator modes. (a) Motor mode, (b) Generator mode

Considering to Fig.1 to find out which vector is appropriate for DTC drive, first by comparing the flux and torque reference values with the calculated ones, Error values of them are determined. Second the error values are applied into two-level hysteresis comparators. The output of both two-level hysteresis comparators that show flux and torque should be increase or decrease. According to the operation condition that can be generator or motor mode, sector that rotor flux is located and based on analysis above the selection of rotor voltage vector selected by table I and II.

H_{Te}		1	0	-1	1	0	-1
Rotor Flux Sector	1	V_6	V_0	V_2	V_5	V_7	V_3
	2	V_1	V_7	V_3	V_6	V_0	V_4
	3	V_2	V_0	V_4	V_1	V_7	V_5
	4	V_3	V_7	V_5	V_2	V_0	V_6
	5	V_4	V_0	V_6	V_3	V_7	V_1
	6	V_5	V_7	V_1	V_4	V_0	V_2

TABLE 1: CLASSICAL DTC LOOK-UP TABLE FOR MOTOR MODE[15]

H_{Te}		1	0	-1	1	0	-1
Rotor Flux Sector	1	V_6	V_0	V_2	V_5	V_7	V_3
	2	V_1	V_7	V_3	V_6	V_0	V_4
	3	V_2	V_0	V_4	V_1	V_7	V_5
	4	V_3	V_7	V_5	V_2	V_0	V_6
	5	V_4	V_0	V_6	V_3	V_7	V_1
	6	V_5	V_7	V_1	V_4	V_0	V_2

TABLE 2: All CLASSICAL DTC LOOK-UP TABLE FOR GANARATOR MODE

3. INDIRECT MATRIX CONVENTOR

Indirect matrix converter (IMC), which consists of separated line and load bridges as presented in Fig.4. IMC is similar to the traditional AC/DC/AC converter system and to previous proposed capacitorless DC link circuits. On the load side, the arrangement has the same conventional inverter as for the AC/DC/AC converter. As a consequence, traditional PWM methods may be used to generate the output voltage waveform.

However, in order to ensure proper operation of this converter, the DC side voltage should always be positive. On the line side, the converter has a rectifier which is similar to traditional one except that the switches are all bidirectional [22]. Typically two types of commutations methods have been proposed which don't require snubber circuits for a IMC.

The first method named rectifier zero current commutation and the second method named rectifier four-step commutation. In these methods, although a complicated control circuit must be added to synchronize the switching of both the PWM rectifier and the PWM inverter but the losses in snubber circuits and the switching losses in the PWM rectifier can be reduced [21]. In this paper, four-step commutation method in the rectifier stage is used. In four-step commutation method, direction of output current and value of input voltage determines the sequence of switching and the commutation reliability.

The process of commutation between phase *A* and *B* is explained with Fig.3. phase A connects to rectifier output through IGBT of switch S_{11} and diode of switch S_{12}. At this point, as it is shown (dotted lines in fig. 3.a) current does not pass from other transistors and diodes. When $i_{DC} > 0$ the following four-step switching sequence is: 1) turn off S_{12} ; 2) turn on S_{31} ; 3) turn off S_{11} ; 4) turn on S_{32} . When $i_{DC} < 0$, the following four- step switching sequence is: 1)turn off S_{11}; 2)turn on S_{32} ; 3)turn off S_{12} ; 4)turn on S_{31} [22].

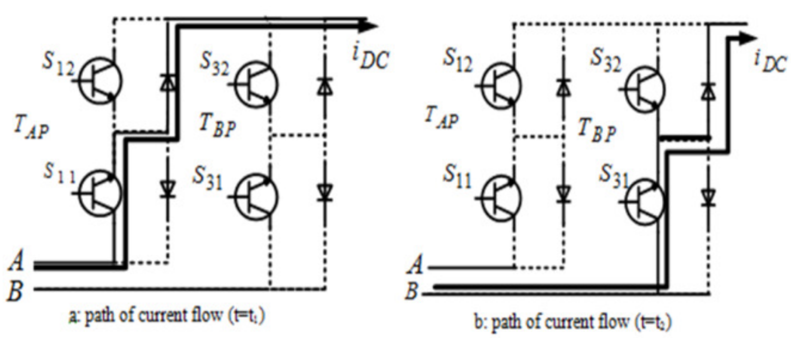

FIGURE 3: Four-Step Commutation Methode Block Diagram[15]

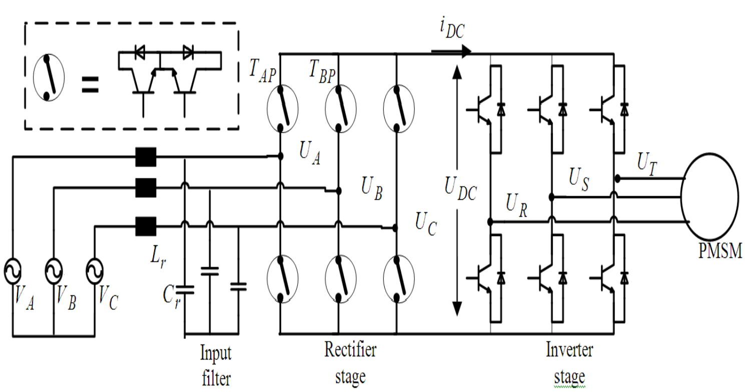

FIGURE 4: Indirect Matrix Converter Structure[15]

4. ACTIVE LEARNING METHOD (ALM)

Active Learning Method (ALM) is a new fuzzy modeling method which has been introduced by Bagheri Shouraki and Honda (1997a).

In contrast to the humans, when human learns an object, in the first step, he grasps its characteristics from much information which apparently looks disorderly, and finds out its tendency, then he finds out the connection with the knowledge formerly learned and he stores it together with the relationship in his brain. The same is true with ALM. When learning the action of a system, it starts from grasping the input-output relations. The input-output data of the object system are collected and the system is modeled. And while memorizing the knowledge, the input-output data are further collected by trial and error, and the system is modeled using the past knowledge and the data. This process is repeated[18].

Active Learning Method is the learning mode in which the learner improves the performance by acquiring information from the behavior of his own [18]. Actually the concept of the ALM is based on the hypothesis that humans interpret information in the form of pattern-like images rather than in numerical or logical forms, in fact it is algorithmically modeled on the intelligent information-handling processes of the human brain, and it is characterized by computing on the basis of intuitive pattern information [10],[16],[17].

ALM considers the behavior of complicated Multi input Multi output (MIMO) systems as collection of simple systems which are single input single output (SISO) systems and the system is expressed by combining them (Fig.5). In the case of two inputs and one output, for example, the input-output relation is plotted on a three-dimensional space [18].

This modeling method not only is similar to human logical thinking but also avoids mathematical complexity. In this method, the learning is done by mutual action with the environment (Fig.6) and promoted by reinforcement learning. The reinforcement learning originated from animal learning psychology and the optimization method like dynamic programming. In this method, the action is

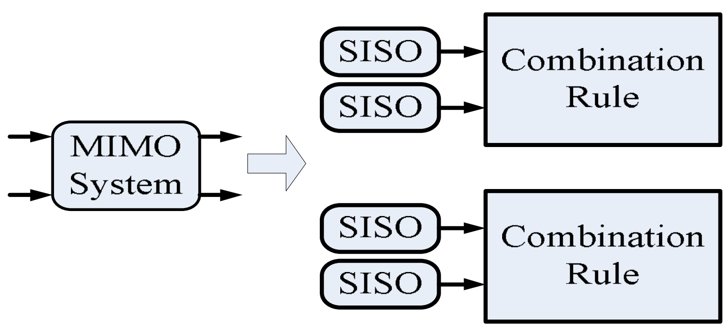

FIGURE 5: Division and Combination of System[14]

reinforced by giving reward or punishment according to the behavior taken in a certain state.
ALM starts with gathering data and projecting them on different data planes. The horizontal axis of each data plane is one of the inputs and the vertical axis is the output. The method called IDS (Ink Drop Spread) which is a processing engine is used to look for a behavior curve, hereafter narrow line, on each data plane. The heart of this learning algorithm is a fuzzy interpolation method which is used to derive a smooth curve among data points [16], [17].

As a matter of fact IDS method is a modeling technique used in the active learning method (ALM), which is a new approach to soft computing. It is characterized by a modeling process which is based on computing that uses intuitive pattern information instead of complex formulas [10].

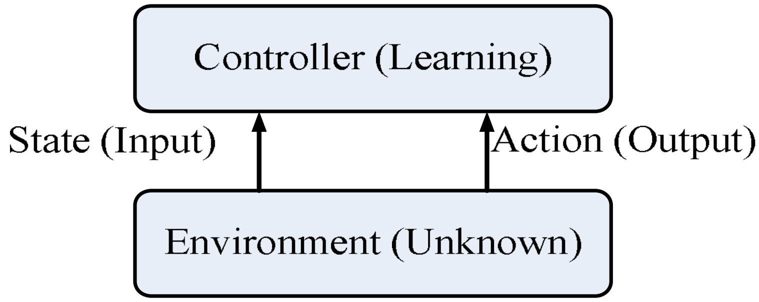

FIGURE 6: Mutual Action with the Environment[14]

5. IV. Ink Drop Spread (IDS)

The basic concept of IDS is to extract the system properties from the input-output data by using fuzzy process. This method searches for continuous possible paths on the interpolated data points on each plane. In this method, we assume that each data point on each data plane is a light source (Fig.7), which has a cone shape illumination pattern. As the distance from these light sources increases, their illumination pattern will interfere and generate new bright areas. The lights interfere with each other and the illuminated pattern appears to show light and darkness. That is, the part where many lights fall is lighter than other part. By combining the light parts continuously, a kind of narrow path expressing the input-output relations can be obtained [18].

By applying IDS method on each data plane, two different types of information would be extracted. One is the narrow path and the other is the deviation of the data points around each narrow path (Fig.8). Each narrow path shows the behavior of output relative to an input and spread of the data points around this path shows the importance degree of that input in overall system behavior. Less deviation of data points around the path presents higher degree of importance and vice versa [18].

Fig.9 illustrates the architecture of an IDS model with two-input, two-partition structure. The IDS model comprises three processing layers. The bottom input layer breaks down input-output data into SISO data, and transfers them to the upper modeling layer. The top inferential layer computes the prediction with the learning data transferred from IDS units. With the exception of the case where a particularly high accuracy is required for an IDS model, the upper layer does not intervene the learning process of IDS units [10],[16]-[19].

Also the spread functions, which show the amount of spread of data on each plane resulting from the effects of other variables, can be calculated using a method presented in [12] by S.B.Shouraki and N.Honda. Then the output of the system can be calculated by (2) [24].

$$y=\frac{\left[\frac{1}{a_1}f_1(x_1)+\frac{1}{a_2}f_2(x_2)+\ldots+\frac{1}{a_n}f_n(x_n)\right]}{\left(\frac{1}{a_1}+\frac{1}{a_2}+\ldots+\frac{1}{a_n}\right)} \quad (2)$$

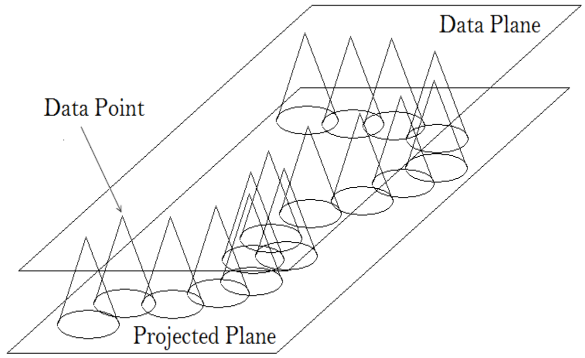

FIGURE 7: Concept of IDS (Ink Drop Spread)[24]

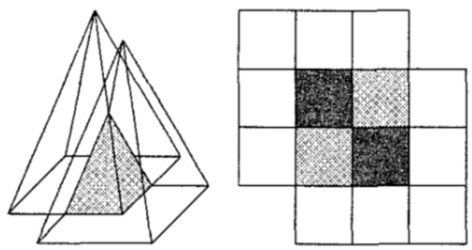

FIGURE 8: Irradiation Pyramid

where
y = the output of system (function)
x1, x2,…, xn = inputs of the system (variables)
f1, f2,… fn = the narrow path functions for plane x-y for each variable
a1, a2,…, an = spread values

6. DTC MODEL BY ALM WITH USING IMC

This research presents and analyses a recommended model of enhanced DTC with the help of ALM, shown in fig10. it uses IMC to feed DFIM's rotor that block control determines unitedly about the appropriate voltage vector in the inverter and rectifier section of IMC. According to the explanations were given about ALM, in this method, with the help of the database, which is obtained by the method of trial and error, the input-output information is collected from the control object and the controller is constructed by the fuzzy-like processing of these data. In the other word some trial inputs are applied to control object and this action is reinforced by giving reward or punishment according to the result. It should be mentioned that trial and error inputs should be

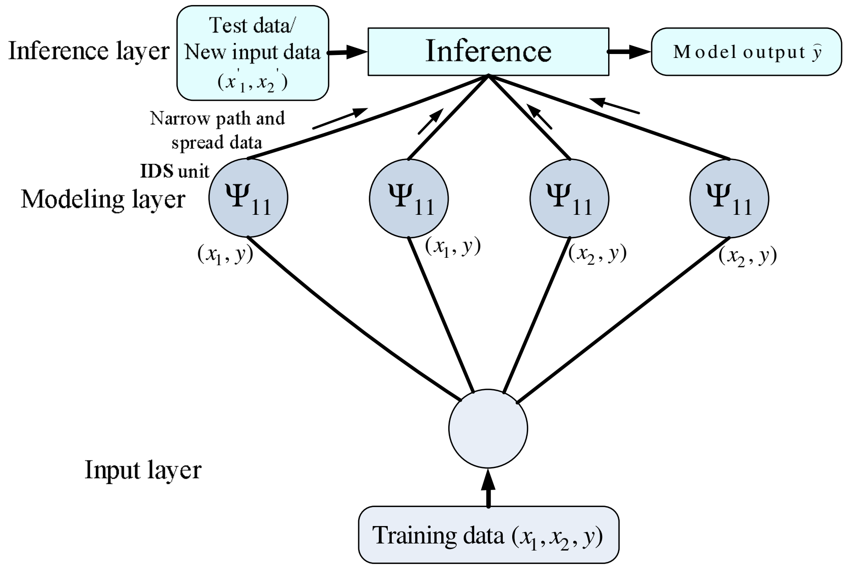

FIGURE 9: Structure of IDS Model[24]

selected so that covers all possible system inputs. On the other hand, by increasing number of trial and error actions, the better model of system can be obtained [10],[14].

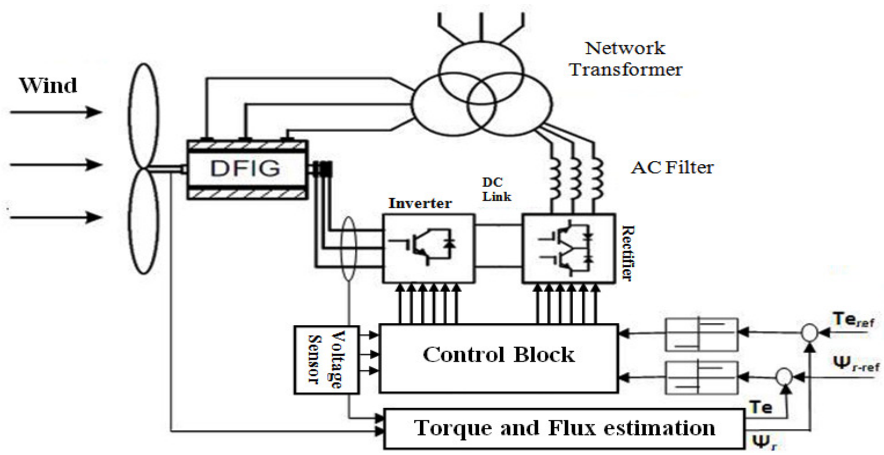

FIGURE 10: DTC using IMC

Regarding the DTC system diagram, shown in Fig10, This research is used IMC to feed DFIM's rotor and the DTC system is a multi input-single output system. Fig. 11 shows the input-output structure of the DTC system control block. According to the ALM basis, this multi input-single output system should be divided into systems with single input and single output (SISO) systems. The DTC control block inputs consist of Torque error, Flux error and rotor Flux angle (position). The rotor flux angle is not considered as an independent input in SISO systems because there is not any direct relationship between rotor flux angle and inverter state (Fig.1). So as mentioned above, the rotor flux is divided into six sectors and this modeling procedure is done for each sector. In the other word, there are 6 couple SISO systems and every couple is for a sector [10].

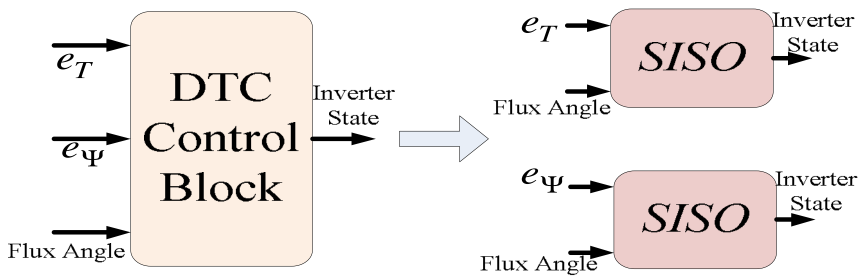

FIGURE 11: Inputs and Outputs of DTC and DTC SISO Models

To apply trial and error inputs Sampling frequency and inverter switching frequency is justified on 8 kHz. To experience different possible errors, torque set value is a random function in proposed model. Some of the sample data obtained by 20000 repetitions are presented in Table 3. This table shows that some inputs lead to improvement in result and some of them worsen the results. So as mentioned above, the inputs which lead to decrease in torque or flux errors should be rewarded and the others should be punished.

These 20000 samples are plotted in a three dimensional space (Fig.12) and the following formula is used to determine the efficiency of each trial action:

$$d_{T_i} = e_{T_i} - e_{T_{i+1}} \quad \text{If} \quad e_{T_i} \geq 0 \tag{3}$$

$$d_{T_i} = e_{T_{i+1}} - e_{T_i} \quad \text{If} \quad e_{T_i} \leq 0 \tag{4}$$

$$M = MAX\,(d_{T_i}) \tag{5}$$

$$E_i = \frac{d_{T_i}}{M} \tag{6}$$

The flux equations and torque equations are same. By equation (6), the efficiency of each applied inverter vector is calculated and Ei determine the magnitude (reward) of each trial and error and its popularity. Any inverter vector with bigger Ei, is reinforced because leads to more improvement in decreasing error. So its relevant vector magnitude in Fig.12 will be bigger [10].

In Fig.12 the plane of trial actions with reward and punishment of data is shown from four different angle of view. The horizontal plane expresses the inverter voltage state and the vertical axis determines the error. The respective correct inverter state of any torque error can be calculated based on these three dimensional plots and the control rules are acquired by these plots, also rules obtained by ALM are similar to classic ones with some minor differences. The rules format is as:
If eT is eT1 and flux sector is α then inverter state is Vm
If eΨ is eΨ1 and flux sector is β then inverter state is Vn
The ALM output in each sector will be achieved by combining SISO models of sector torque and flux errors. DTC total system model is achieved by combining 12 SISO models of six sectors and this combination is based on the sum of adaptability of each SISO model. Equation (7) is used for calculating output by combining SISO outputs [10].

$$y = \alpha_T \times y_T + \alpha_\varphi \times y_\psi \tag{7}$$

Where α is the adaptability of each SISO, determined by the efficiency (Ei) of each case. By this equation the output of a case in sector one will be a compromise of sector one torque and flux error SISO systems outputs [10].

$e_{T\ (NM)}$	$e\Psi$ (wb)	Flux Sector	Inverter vector
3.5918541	-0.023571	1	2
0.839314	-0.03453	1	2
-1.42841	-0.18675463	1	2
0.7784831	-0.1834733	1	3
-0.512115	-0.0021443	1	3
1.63797	0.0523732	1	3
-1.346901	0.03453232	1	3
-2.19589	0.0737643	1	5
- 3.219250	-0.0348734	1	5
2.432973	-0.20013	1	5
1.646507	-0.19714	1	5
3.2917926	-0.032432	1	6
1.4556623	-0.0347334	1	6
-0.3716126	-0.042329	1	6

TABLE 3: SOME SAMPLE TRIALS

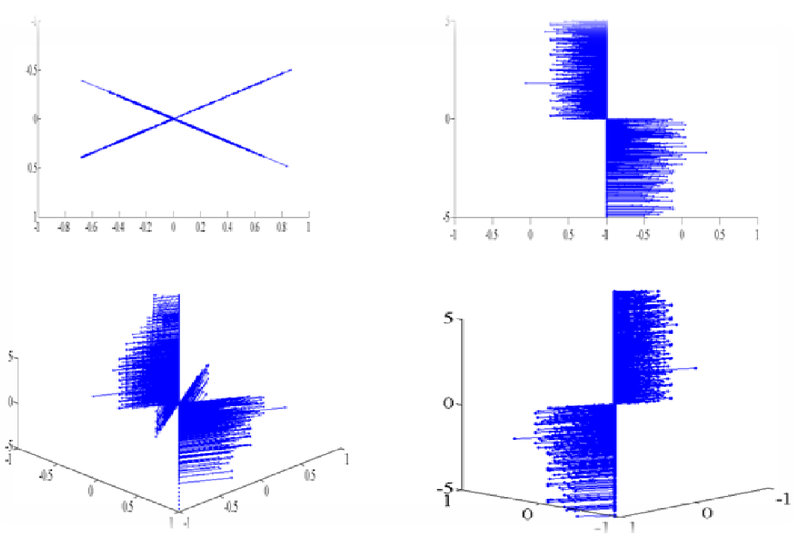

FIGURE 12: IDS irradiation pattern for SISO system with torque error as input and inverter vector as output

7. SIMULATION RESULT AND COMPARISON WITH CLASSIC METHODS

The result of torque control and rotor flux for both DTC based on IMC and the proposed method is presented in Fig.13-fig.16. Good dynamic behavior of torque responses when reference torque suddenly changes from 100Nm to -100Nm at time t=0.3 is shown. As can be seen, the ALM leads to less deviation from the desired value of torque and rotor flux (reference value) rather than the conventional DTC, this is due to its adaptability with motor model and the total system, also obviously switching frequency is decreased. According to the torque figures, ripple reduction of about 25% during using this method is created. Also by applying this method to the DTC, ripple rotor flux is reduced around 15%. Fig.17 and fig.18 show the flux response, flux circular trajectory and rotor flux sector. DC-link voltage of IMC is shown in Fig.19, Also Fig.20 and fig.21 show the 3-phase stator and rotor currents. These currents are sinusoidal and demonstrates that there are no low order harmonics.

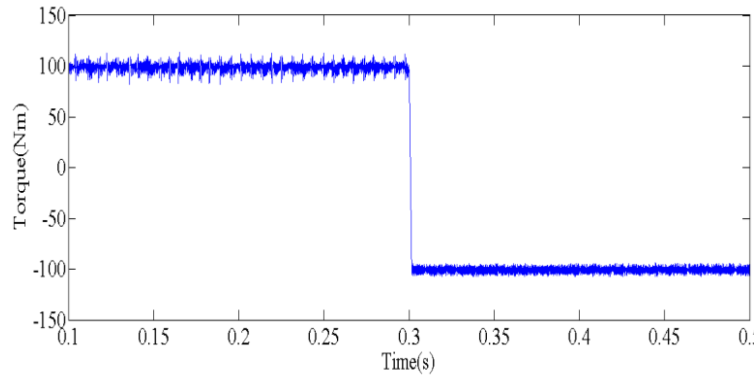

FIGURE 13: Output torque of DTC based on IMC

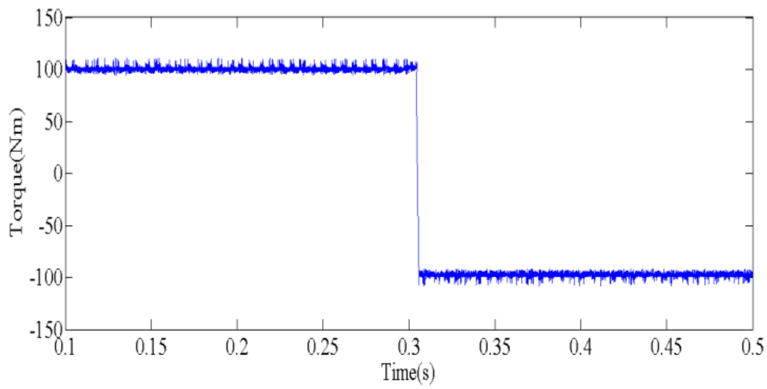

FIGURE 14: Output torque of enhanced DTC based on IMC by ALM

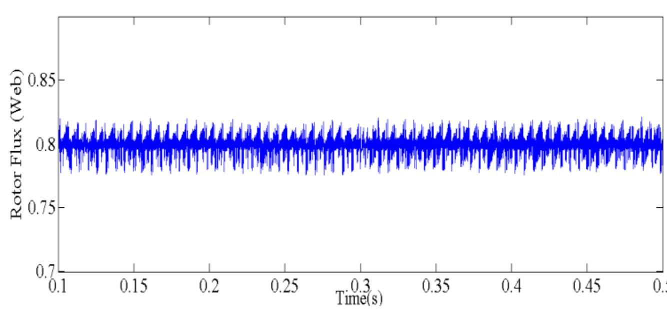

FIGURE 15: Flux response of DTC based on IMC

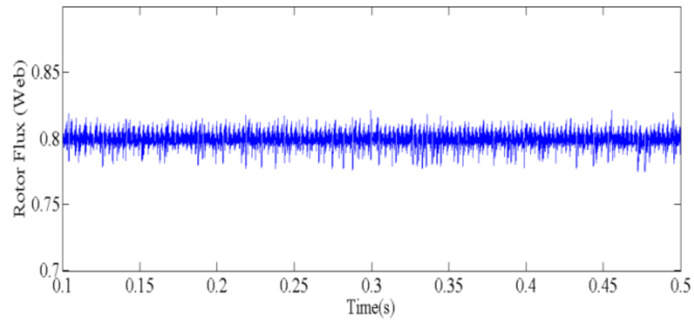

FIGURE 16: Flux response enhanced DTC based on IMC by ALM

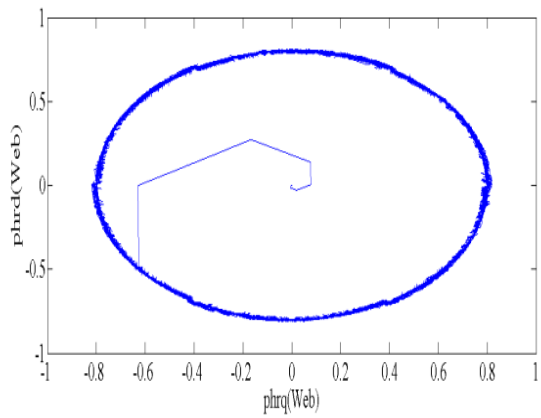

FIGURE 17: Flux circular trajectory

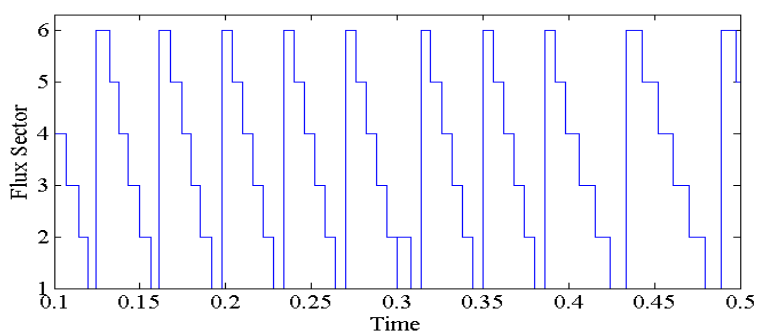

FIGURE 18: rotor flux sector

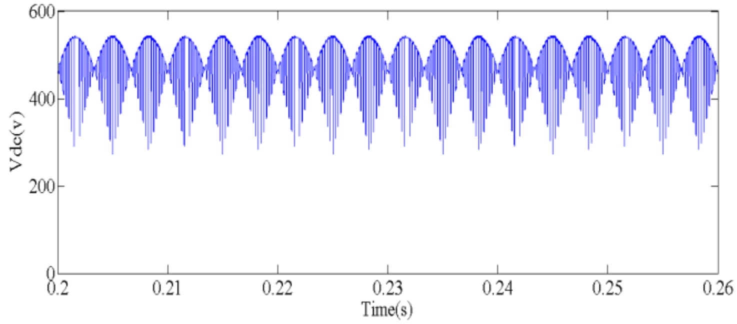

FIGURE 19: DC voltage of IMC

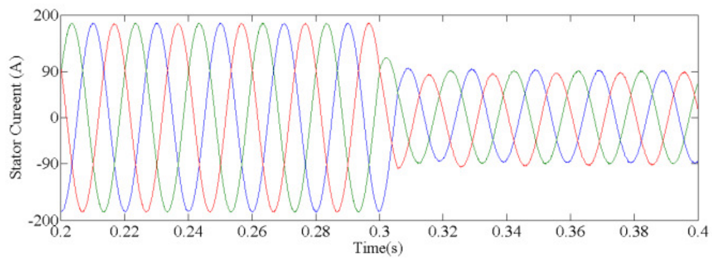

FIGURE 20: Three phase stator current

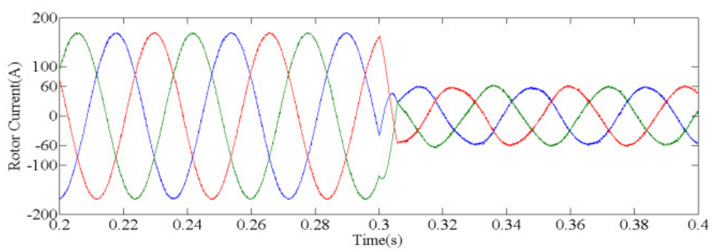

FIGURE 21: Three phase rotor current

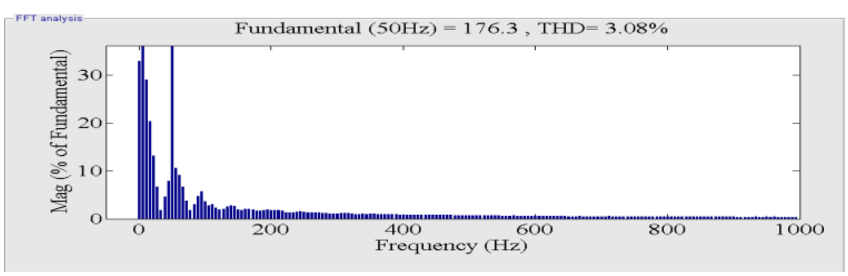

FIGURE 22: Current harmonic spectra of stator

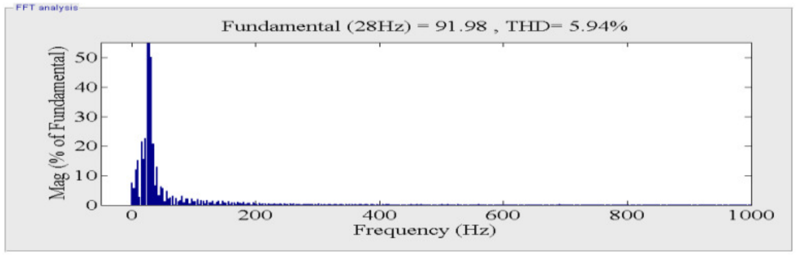

FIGURE 23: Current harmonic spectra of rotor

8. CONCLUSION

This paper tries to explore reducing of flux and torque ripple which are the inherent negative characteristics of DTC by an actively trial and error method called Active Learning Method for Doubly Fed Induction Machine based on Indirect Matrix Converter. Using DTC strategy with IMC result that the benefits of both method simultaneously obtained. The advantages are: fast response in torque control, regeneration capability, near sinusoidal stator and rotor current. Also usage of four-step commutation in rectifier stage of IMC which is the source of feeding the rotor is analysed to reduce the losses' caused by snubber circuit. In addition the concept Ink Drop Spread (IDS) is applied to handle different modeling target to predict on the data and get a behavior curve in DTC. Finally the simulation results confirm that a significant torque and stator flux ripple reduction are obtained.

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The Evaluation of Soil Liquefaction Potential Using Shear Wave Velocity Based on Empirical Relationships

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Abstract

The liquefaction resistance of soils can be evaluated using laboratory tests such as cyclic simple shear, cyclic triaxial, cyclic torsional shear, and field methods such as Standard Penetration Test (SPT), Cone Penetration Test (CPT), and Shear Wave Velocity (Vs). The present study is aimed at comparing the results of two field methods used to evaluate liquefaction resistance of soil, i.e. SPT based on simplified procedure proposed by Seed and Idriss (1985) and shear wave velocity (Vs) on the basis of Andrus et al. (2004) process using empirical relationships between them. Iwasaki's (1982) method is used to measure the liquefaction potential index for both of them. The study area is a part of south and southeast of Tehran. It is observed that there is not a perfect agreement between the results of two methods based on five empirical relationships assuming cemented and non-cemented conditions for (OF) soil. Liquefaction potential index (PL) value in SPT test was found to be more than Vs method.

Keywords: Liquefaction, Liquefaction Potential Index (PL), Shear Wave Velocity (Vs), South of Tehran, Standard Penetration Test (SPT).

1. INTRODUCTION

The simplified procedure is widely used to predict liquefaction resistance of soils world. It was originally developed by Seed and Idriss [1] using Standard Penetration Test (SPT) blow counts correlated with a parameter representing the seismic loading on the soil, called cyclic stress ratio (CSR). This procedure has undergone several revisions and updated [2, 3, 4]. In addition, procedures have been developed based on the Cone Penetration Test (CPT), Becker Penetration Test (BPT) and small-strain Shear Wave Velocity (Vs) measurements. The use of Vs to determine the liquefaction resistance is suitable, because both Vs and liquefaction resistance are influenced by such factors as; confining stress, soil type/plasticity and relative density [5, 6, 7] and in situ Vs can be measured by several seismic tests including cross hole, down hole, seismic cone penetrometer (SCPT), suspension logger and spectral analysis of surface waves (SASW). During the past two decades, several procedures have been proposed to estimate liquefaction resistance based on Vs. These procedures were developed from laboratory studies [8, 9, 10, 11, 12, 13, 14, 15], analytical studies [16, 17], penetration- Vs equations [18, 19], in situ Vs measurements at earthquake shaken site [20, 21, 22]. Some of these procedures follow the general format of Seed- Idriss simplified procedure which the Vs is corrected to a reference vertical stress and correlated with the cyclic stress ratio. This paper presents the results of the comparison between two Vs and SPT methods of soil liquefaction potential evaluation in the south of Tehran. Furthermore, liquefaction potential index (PL) is calculated by Iwasaki et al. [23] procedure for both aforementioned methods.

2. GENERAL CONDITION AND SOIL STRATIFICATION

In order to evaluate the liquefaction potential of soils using two field methods, geotechnical information of 67 boreholes in the south and southeast of Tehran including 11 to 16 municipality areas were collected (Figure 1). As mentioned before, the types of soil and geotechnical properties can affect the liquefaction potential. In this study, the gravely sand, silty sand and silty soils were studied.

FIGURE 1: The study area and PGA distribution throughout Tehran for an earthquake corresponding to 475 year return period [24].

3. ANALYSIS OF BOREHOLES TO EVALUATE THE LIQUEFACTION POTENTIAL

The peak ground acceleration (PGA) is necessary for the analysis of boreholes to evaluate liquefaction potential of soils. According to Figure 1, PGA values were selected in each boreholes position. In addition, the depth of ground water table in the assessment of liquefaction potential of soils was considered. To define critical ground water level in boreholes, the maps of variations of underground water depth in Tehran Plain were used. In Shear wave velocity (Vs) measurement method based on Andrus et al. [25] process for assessing liquefaction potential, Vs amounts were calculated using empirical equations between shear wave velocity and SPT blow count (N) for all soil types as follow [26]:

$$V_s = 61.N^{0.5} \quad (1)$$
$$V_s = 97.N^{0.314} \quad (2)$$
$$V_s = 76.N^{0.33} \quad (3)$$
$$V_s = 121.N^{0.27} \quad (4)$$
$$V_s = 22.N^{0.85} \quad (5)$$

4. ASSESSMENT OF LIQUEFACTION POTENTIAL

The evaluation procedures based on Standard Penetration Test (SPT) (Seed and Idriss, 1985, simplified method) and measurement of shear wave velocity (Vs) (Andrus and Stokoe, 2004) require the measurement of three parameters: (1) the level of cyclic loading on the soil caused by the earthquake, expressed as a cyclic stress ratio (CSR); (2) the stiffness of the soil, expressed as a overburden stress corrected SPT blow count and shear wave velocity; and (3) the resistance of the soil to liquefaction, expressed as a cyclic resistance ratio (CRR). Guidelines for calculating each parameter are presented below:

4.1 Cyclic stress ratio (CSR)

The cyclic stress ratio at a particular depth in at soil deposit level can be measured by Eq.(6) in both methods [1]:

$$CSR = \frac{\tau_{av}}{\sigma'_v} = 0.65\left[\frac{a_{max}}{g}\right]\left[\frac{\sigma_v}{\sigma'_v}\right] \times r_d \quad (6)$$

Where a_{max}, is the peak horizontal ground surface acceleration (based on Figure 1), g is the acceleration of gravity, σ_V is the total vertical (overburden) stress at the desired depth, σ'_V is the effective overburden stress at the same depth, and r_d is the shear stress reduction coefficient (Figure 2).

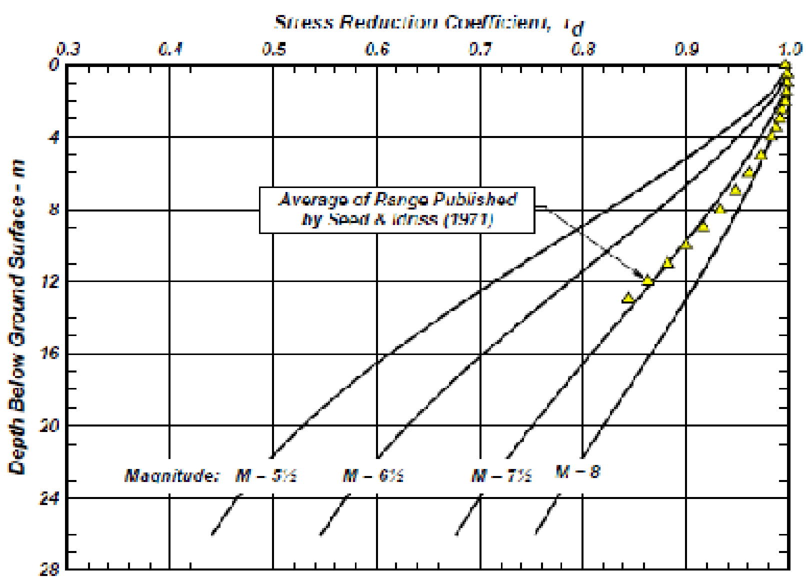


FIGURE 2: Variations of stress reduction coefficient with depth and earthquake magnitudes [27, 28]

4.2 Corrected SPT Blowcount and Shear Wave Velocity

In addition to the fines content and the grain characteristics, other factors affect SPT results, as noted in Table 1. Eq. (7) incorporates these factors:

$$(N_1)_{60} = N_{SPT}.C_N.C_E.C_B.C_R.C_S \tag{7}$$

Where $(N_1)_{60}$ corrected standard penetration test blow count, N_{SPT} represents the measured standard penetration resistance, C_N is a factor to normalize, N_{SPT} represents the effective overburden stress, C_E, represents the correction for hammer energy ratio (ER), C_B is the correction factor for borehole diameter, C_R is the correction factor for rod length, and C_S is the correction factor for samplers with or without liners.

Factor	Equipment Variable	Term	Correction
Overburden Pressure		C_N	C Pa=100kPa
Energy ratio	Donut Hammer Safety Hammer Automatic-Trip Donut-Type Hammer	C_E	0.5 to 1.0 0.7 to 1.2 0.8 to 1.3
Borehole diameter	65 mm to 115 mm 150 mm 200 mm	C_B	1.0 1.05 1.15
Rod length	3 m to 4 m 4 m to 6 m 6 m to 10 m 10 m to 30 m $\rangle$30m	C_R	0.75 0.85 0.95 1.0 $\langle$1.0
Sampling method	Standard sampler Sampler without liners	C_S	1.0 1.1 to 1.3

TABLE 1: Correction Factors of SPT [29]

In the procedure of liquefaction potential evaluation proposed by Andrus et al. [24], shear wave velocity should be corrected to overburden stress. Eq.(8) is suggested:

$$V_{S1} = V_S(\frac{P_a}{\sigma_V'})^{0.25}.(\frac{0.5}{K_0'})^{0.125} \tag{8}$$

Where V_s is the shear wave velocity (m/s), V_{s1} is the stress-corrected shear wave velocity (m/s), P_a is the atmosphere pressure equal to 100kPa, σ'_V, shows the effective overburden stress and K_0', is the coefficient of effective earth pressure (in this study assumed equal to 0.5).

4.3 Cyclic Resistance Ratio (CRR)

In the simplified procedure, Figure 3 is a graph of calculated CSR and corresponding $(N_1)_{60}$ data from sites where liquefaction effects were or not observed following the past earthquakes of approximately 7.5 magnitude. CRR Curves on this graph were conservatively positioned to separate the regions with data indicative of the liquefaction from the regions with data indicative of non-liquefaction. Curves were developed for granular soils with the fine contents of 5% or less, 15% and 35% as shown on the plot.

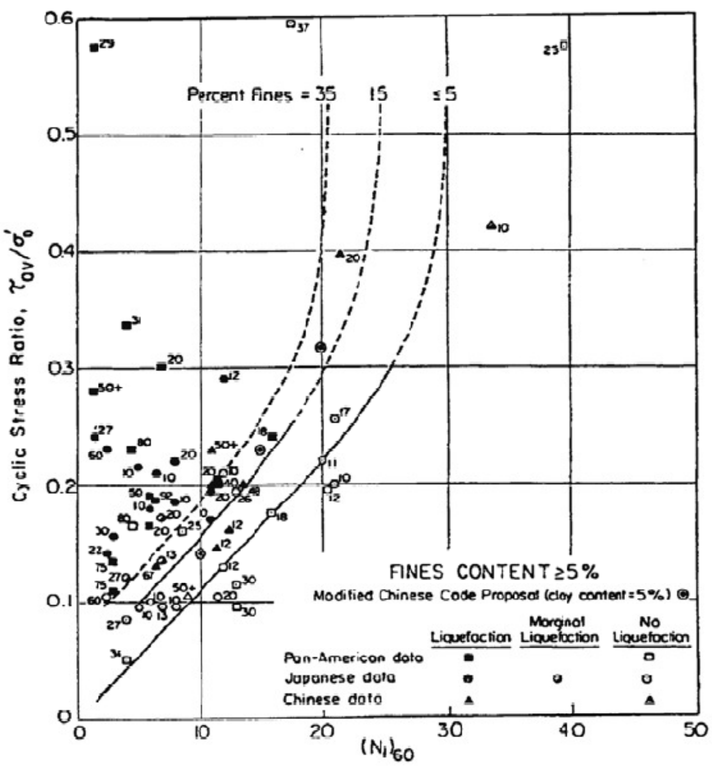


FIGURE 3: The liquefaction resistance curves by Seed et al. for the earthquakes of 7.5 magnitude [4]

Furthermore, in shear wave velocity measurement method, the cyclic resistance ratio (CRR) can be considered as the value of CSR that separates the liquefaction and non-liquefaction occurrences for a given V_{s1}. Shown in Figure 4 are the CRR-V_{s1} curves by Andrus et al. [24] for the earthquakes of 7.5 magnitudes.

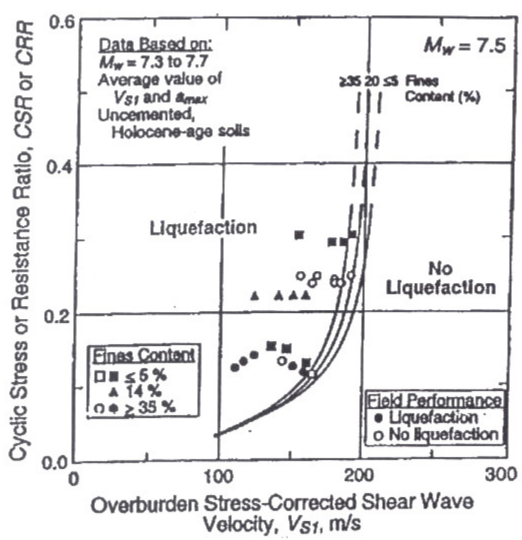


FIGURE 4: The liquefaction resistance curves by Andrus et al. [24] for the 7.5 magnitude earthquakes

The CRR-V_{s1} curves shown in Figure 4 can be defined by Eq. (9):

$$CRR = K_{a2}\{0.022(\frac{K_{a1}V_{s1}}{100})^2 + 2.8(\frac{1}{V_{s1}^* - K_{a1}V_{s1}} - \frac{1}{V_{s1}^*})\}MSF \tag{9}$$

Where MSF is the magnitude scaling factor, V_{s1}^* is the limiting up value of V_{s1} for liquefaction occurrence, K_{a1} is a factor to correct for high V_{s1} values caused by aging, and K_{a2} is a factor to correct the influence of age on CRR. Andrus and Stokoe [24] suggest the following relationships for estimating MSF and V_{s1}^*:

$$MSF = (\frac{M_w}{7.5})^{-2.56} \tag{10}$$

$$V_{s1}^* = 215 \qquad FC \leq 5\% \text{ (FC=Fines content)} \tag{11a}$$

$$V_{s1}^* = 215 - 0.5(FC - 5) \qquad 5 \prec FC \prec 35\% \tag{11b}$$

$$V_{s1}^* = 200 \qquad FC \geq 35\% \tag{11c}$$

In this study, the earthquake magnitude (Mw) is assumed 7.5. Therefore, MSF is equal to 1.0. Both K_{a1} and K_{a2} factors are equal to 1.0 for uncemented soils of Holocene age. For the older and cemented soils, K_{a1} factor is evaluated using curves in figure 5. If the soil conditions are unknown and penetration data is not available, the assumed value for K_{a1} is 0.6 [24].

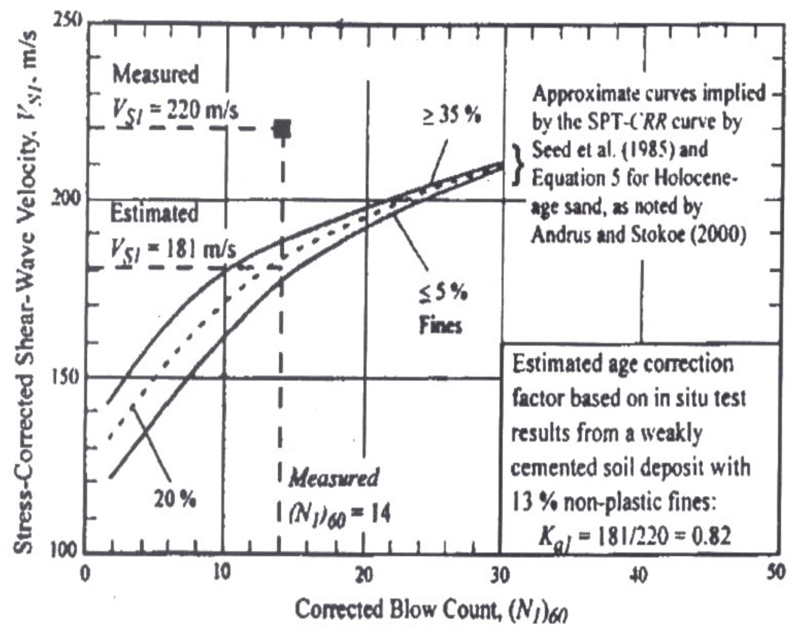


FIGURE 5: Suggested method for estimating K_{a1} from SPT and V_s measurements at the same site [24]

In both methods, if the effective overburden stress is greater than 100kPa at in question depth, CRR value is corrected using following equations and Figure 6. [30]:

$$CRR_J = CRR.K_\sigma \tag{12}$$

$$K_\sigma = (\frac{\sigma_V^{'}}{100})^{f-1} \tag{13}$$

Where K_σ is the overburden correction factor, σ'_V is the effective overburden stress and f is an exponent that is a function of site conditions including relative density, stress history, aging and over consolidation ratio. For the relative densities between 40% and 60%, f= 0.7-0.8 and for the relative densities between 60% and 80%, f= 0.6-0.7.

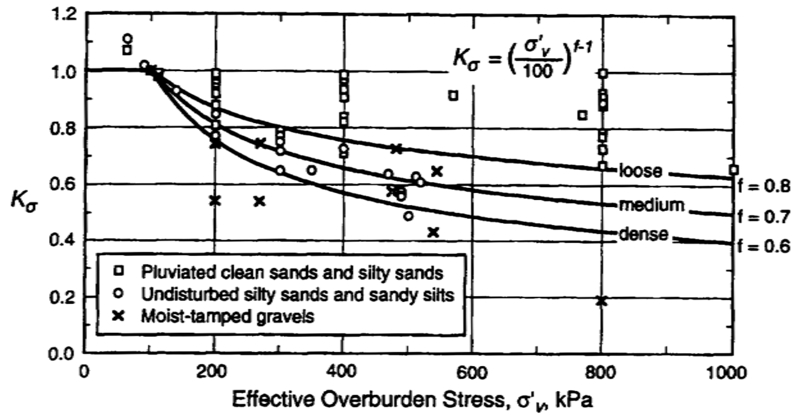


FIGURE 6: Variations of K_σ values versus effective overburden stress [30]

4.4 Safety Factor

One way to quantify the potential for liquefaction is the safety factor. Factor of safety (F_S) against liquefaction is commonly measured using the following formula:

—— 14)

Where CRR_J is corrected value of CRR estimated by Eq.(12). By convention, the liquefaction is predicted to occur when $F_S \leq 1$.When $F_S > 1$, the liquefaction is predicted not to occur.

4.5 Liquefaction Potential Index (PL)

Iwasaki et al [23] quantified the severity of possible liquefaction at any site by introducing a factor called the liquefaction potential index (P_L) defined as:

(15)

$F(Z)= 1-F_S$ (16)
$W(Z)=10-0.5Z$ (17)

Where Z is the depth in question, F (Z) is the function of the liquefaction safety factor (F_S) and W(Z) is the function of depth. The range of P_L according to Table 2 is from 0 to 100. In this study PL values were measured and then compared for both methods.

P_L- Value	Liquefaction risk and investigation/ Countermeasures needed
$P_L=0$	Liquefaction risk is very low. Detailed investigation is not generally needed.
$0<P_L\leq 5$	Liquefaction risk is low. Further detailed investigation is needed especially for the important structures.
$5<P_L\leq 15$	Liquefaction risk is high. Further detailed investigation is needed for structures. A countermeasure of liquefaction is generally needed.
$P_L> 15$	Liquefaction risk is very high. Detailed investigation and countermeasures are needed.

TABLE 2: Liquefaction potential index (P_L) and its describes [23]

5. EVALUATING THE RESULTS OF DATA ANALYSIS

The results of the data analysis based on both methods mentioned above using five empirical relationships as:

1- Liquefaction potential index (P_L) values based on SPT method is observed in Table 3. Results show that 51% of the data according to Table 2, ranking 2 have low liquefaction risk.

PL- Value	P_L=0	0<P_L≤ 5	5<P_L≤ 15	P_L> 15
Number	15	34	18	0
Percent	23	51	26	0

TABLE 3: Liquefaction potential index (P_L) values based on SPT analysis

2- P_L values based on shear wave velocity (Vs) method using five empirical relationships (Eqs.1 to 5) in two uncemented and cemented soils are seen in Tables 4 and 5. The results show that the used relations are overestimated and most of them have shown nonliquefaction condition for soils in the studied area.

PL- Value	P_L=0	0<P_L≤ 5	5<P_L≤ 15	P_L> 15
		Eq.1		
Number	63	3	1	0
Percent	94	4.5	1.5	0
		Eq.2		
Number	60	6	1	0
Percent	90	9	1	0
		Eq.3		
Number	61	6	0	0
Percent	91	9	0	0
		Eq.4		
Number	60	7	0	0
Percent	89.5	10.5	0	0
		Eq.5		
Number	61	6	0	0
Percent	91	9	0	0

TABLE 4: The liquefaction potential index (P_L) values based on Vs analysis in the cemented soils

PL- Value	P_L=0	0<P_L≤ 5	5<P_L≤ 15	P_L> 15
		Eq.1		
Number	66	1	0	0
Percent	98.5	1.5	0	0
		Eq.2		
Number	65	2	0	0
Percent	97	3	0	0
		Eq.3		
Number	66	1	0	0
Percent	98.5	1.5	0	0
		Eq.4		
Number	66	1	0	0
Percent	98.5	1.5	0	0
		Eq.5		
Number	67	0	0	0
Percent	100	0	0	0

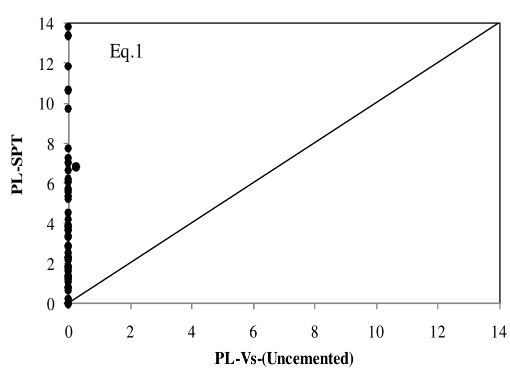
TABLE 5: Liquefaction potential index (P_L) values based on Vs analysis in the uncemented soils

3- In 67 boreholes, about 529 soil layers analyzed and liquefaction potential of soils calculated the results of which for all types of soils are presented in Table 6. **The r**esults show that there is no compatibility between two procedures in soil liquefaction expression for two states. On the contrary, both of them present suitable harmony in nonliquefaction condition for soils.

Type of Soil	**SPT**	**Vs Cemented**				
	Liquefied	**Liquefied in Eq.1**	**Liquefied in Eq.2**	**Liquefied in Eq.3**	**Liquefied in Eq.4**	**Liquefied in Eq.5**
Silt	57	2	2	1	1	5
Sand	81	2	5	3	5	3
Gravel	16	0	0	2	2	0
		Uncemented				
Silt	57	1	1	0	0	0
Sand	81	0	1	1	1	0
Gravel	16	0	0	0	0	0
	SPT	**Vs Cemented**				
Type of Soil	**Non Liquefied**	**Non Liquefied in Eq.1**	**Non Liquefied in Eq.2**	**Non Liquefied in Eq.3**	**Non Liquefied in Eq.4**	**Non Liquefied in Eq.5**
Silt	123	178	178	179	179	175
Sand	193	272	269	271	269	271
Gravel	59	75	75	73	73	75
		Uncemented				
Silt	123	179	179	180	180	180
Sand	193	274	273	273	273	274
Gravel	59	75	75	75	75	75

TABLE 6: The results of the estimating liquefaction potential in question depths using SPT and Vs methods based on five empirical relationships

4- The comparative diagrams related to the liquefaction potential index (PL) values based on SPT and shear wave velocity methods in uncemented and cemented states for soils are presented in Figures 7 and 8. As seen, the results are consistent with the values in the tables shown above and the liquefaction potential of soils that is based on shear wave velocity method is overestimated using empirical relationships.



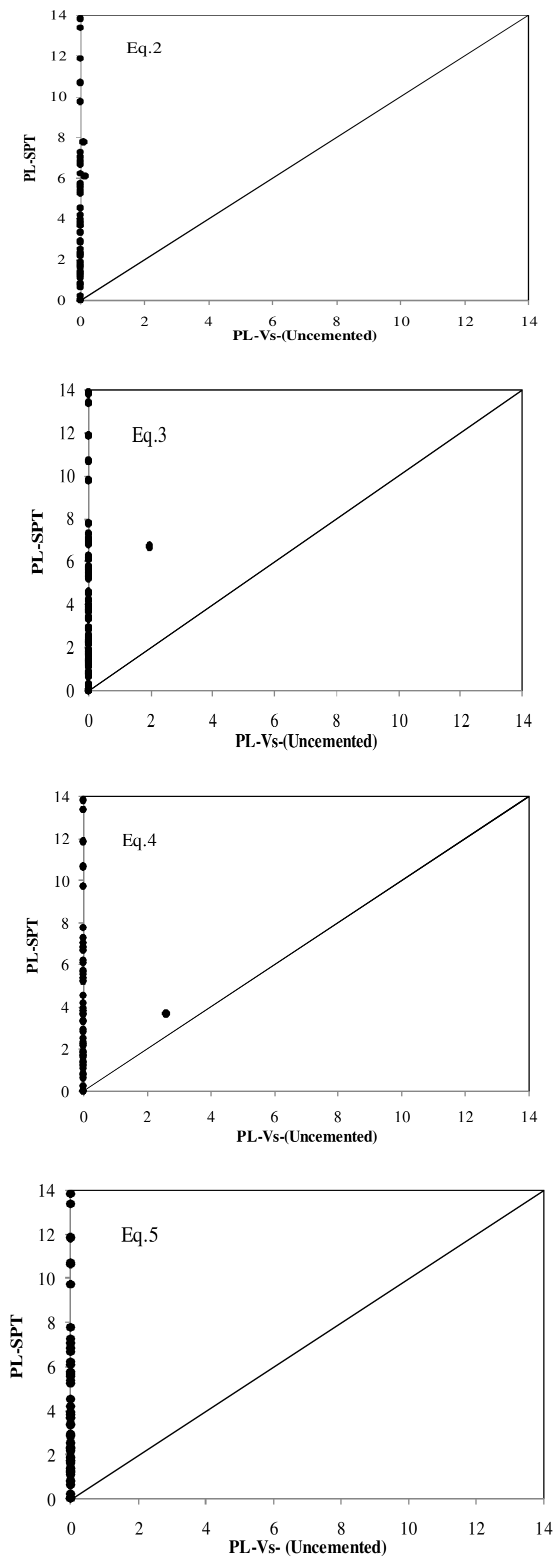
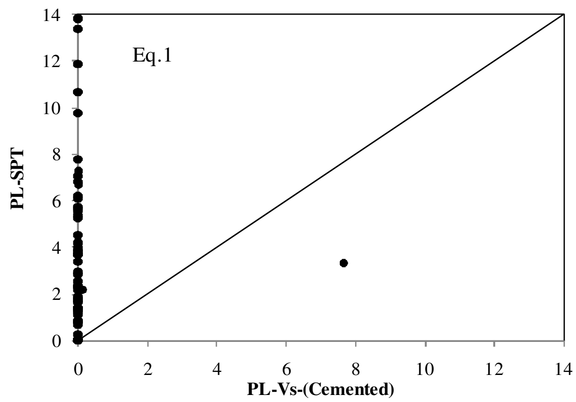
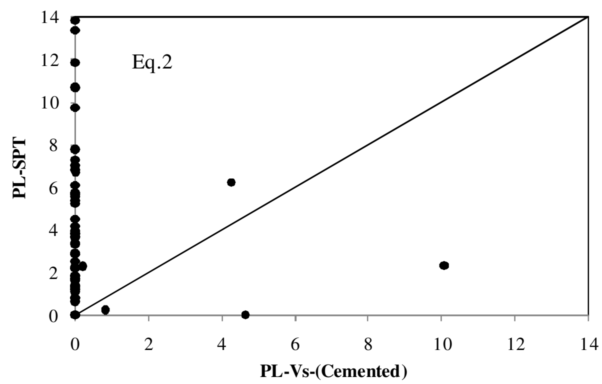
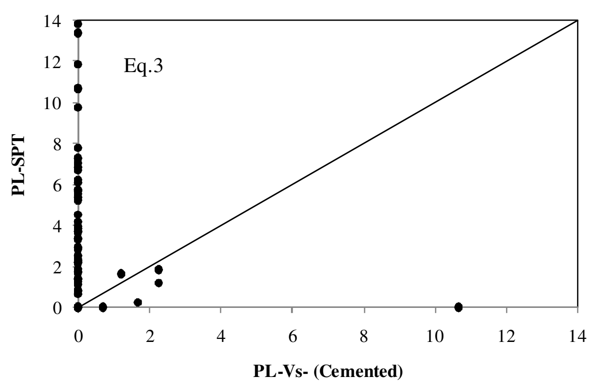
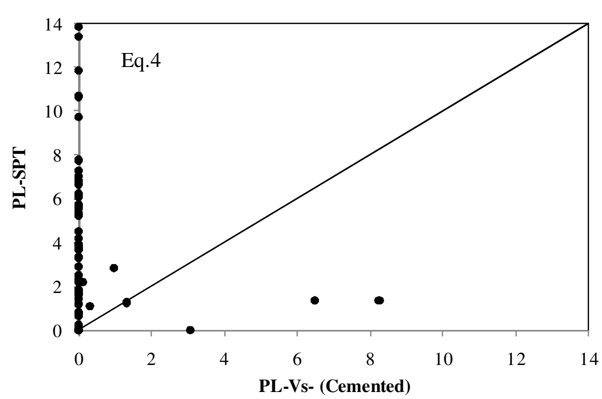


FIGURE 7: The comparison of PL values based on SPT and Vs analyses in the deep layers of soil in uncemented state


Eq.1
PL-SPT
PL-Vs-(Cemented)
0
2
4
6
8
10
12
14


Eq.2
PL-SPT
PL-Vs-(Cemented)
0
2
4
6
8
10
12
14


Eq.3
PL-SPT
PL-Vs- (Cemented)
0
2
4
6
8
10
12
14


Eq.4
PL-SPT
PL-Vs- (Cemented)
0
2
4
6
8
10
12
14

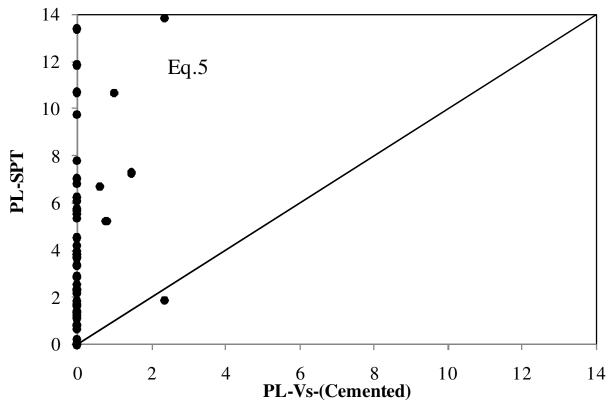


FIGURE 8: The comparison of PL values based on SPT and Vs analyses in the deep layers of soil in cemented sate

5- In order for the accurate /precise comparison, the consistency and mismatch of two methods at the same depth based on safety factor values were evaluated. The results are presented in Table 7. As illustrated below, there is proper/perfect adaption in the non-liquefaction of soil condition.

Type of Soil	State of Soil	Liquefied in SPT and Vs-Eq.1	Liquefied in SPT and Vs-Eq.2	Liquefied in SPT and Vs-Eq.3	Liquefied in SPT and Vs-Eq.4	Liquefied in SPT and Vs-Eq.5
Silt	**Cemented**	1	0	1	0	4
	Uncemented	1	1	0	0	0
Sand	**Cemented**	2	2	1	0	3
	Uncemented	0	1	1	1	0
Gravel	**Cemented**	0	0	2	0	0
	Uncemented	0	0	0	0	0
		Non-Liquefied in SPT and Vs-Eq.1	**Non-Liquefied in SPT and Vs-Eq.2**	**Non-Liquefied in SPT and Vs-Eq.3**	**Non-Liquefied in SPT and Vs-Eq.4**	**Non-Liquefied in SPT and Vs-Eq.5**
Silt	**Cemented**	114	115	114	115	111
	Uncemented	114	114	115	115	115
Sand	**Cemented**	192	192	193	194	191
	Uncemented	194	193	193	193	194
Gravel	**Cemented**	58	58	56	58	58
	Uncemented	58	58	56	58	58

TABLE 7: The comparison of analyses in layers at the same depth based on SPT and Vs methods using Five empirical relationships

As it can be observed, there is a significant difference between Seed and Idriss (1971-1985) simplified procedure based on Standard Penetration Test (SPT) results and the field performance curves proposed by Andrus et al. (2004) established on Shear wave velocity (Vs). This difference might be due to the inherent uncertainties in field performance data methods and empirical relationships.

The uncertainties in the field performance data methods include:
1- The uncertainties in the plasticity of the fines in the in situ soils.
2- Using post earthquake properties that do not exactly reflect the initial soil states before earthquakes.

3- The assumption that CRR_{field} is equal to CSR obtained from Seed and Idriss [1]. This may result in a significant overestimation of CRR_{field} when the safety factor is less than 1.
4- In determining the cyclic strength ratio (CRR) in shear wave velocity method the soil cementation factors (K_{a1} and K_{a2}) are calculated. The value of these parameters proposed by Andrus and Stokoe may be inappropriate in the study area.
5- The maximum shear wave velocity (V_{s1}^{*}) values for occurring liquefaction in soil recommended by Andrus et al. [25] may be unsuitable for the study area.
6- The value of parameters a and b in CRR equation in the shear wave velocity method perhaps is improper for the data range studies.
The uncertainties in the empirical relationships are:
1- The standard penetration resistance (N_{SPT}) is not estimated accurately and the test apparatus can be in error.
2- The empirical relationships used for the study perhaps is inappropriate for the data range and the type of soils in the study area.

6. CONCLUSION

The present study investigated the two field methods used to evaluate liquefaction potential of soils including Standard penetration Test (SPT) and Shear wave velocity test (Vs) based on empirical relationships between them. The comparison of the safety factor values and liquefaction potential index revealed that the severity/seriousness of liquefaction occurrence in the studied area based on Vs method is was lower than the one based on SPT based method. Furthermore, it can be observed that the relationships between Standard Penetration Test and shear wave velocity are not appropriate. Because the relationships used in the present study are dependent on soil type, fines content (clay and silt), type of tests and their accuracy, it would be much safer to perform both methods for the same place and then compare the results in order to evaluate the liquefaction potential. Last but not least, further studies are called for to obtain better relationships based on the type of soils within the area of the study.

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A Security Architecture for Automated Social Engineering (ASE) Attacks over Fiber-Wireless (FiWi) Access Networks

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Abstract

Future communication networks will integrate `SSS' concepts such as social networking, social networking device, and social desktop. In this paper, we focus on applications over social networking sites (SNS). Due to emerging bandwidth-hungry applications over SNS, hybrid fiber-wireless (FiWi) access networks are a promising solution to mitigate the last mile bandwidth bottleneck. SNS are particularly vulnerable to Automated Social Engineering (ASE) attacks due to their powerful information gathering functionalities. We discuss how integrated FiWi access networks supporting SNS systems perform, and how they can deal with threats related to ASE. In addition, we explain how an ASE attack may be launched from different networking platforms and propose a security architecture for ASE attacks over FiWi access networks.

Keywords: Social Networking Sites (SNS), Automated Social Engineering (ASE), Hybrid Fiber-Wireless (FiWi) Access Networks, WiMAX BS, EPON (ONU, OLT), ONU-BS.

1. INTRODUCTION

Future communication networks will enrich our lives by supporting enormous data rates for end users. Home networking will allow end users to access online games, video on demand, high-definition television, radio, audio, web, phone, alarm systems, home automation, and health care anytime, anywhere, and in any format by assisting consumers in maintaining their independence as they evolve from the same platform [1].

Future broadband access networks will be bimodal, capitalizing on the respective strengths of optical and wireless technologies and smartly merging them in order to realize future-proof fiber-wireless (FiWi) networks in support of a plethora of services for subscribers [2]. FiWi access networks mitigate the first/last mile and backhaul bandwidth bottlenecks, increase network coverage, and provide user mobility. In most of today's greenfield network deployments fiber rather than copper cables are installed for broadband access. Due to applications such as file sharing, chatting, audio, video, gaming, online communities over social networking sites (SNS), e.g., Facebook, bandwidth demands keep increasing day by day. Hence, home and access networks must not only support high-speed, plug-n-play, mobility, and QoS, but must also be scalable up- and down-market, and retrofit in home network installations, small business to large enterprise campuses, and from rural to urban areas, thus enhancing the revenue for operators and vendors. Despite their optical transparency, high capacity, and cost-saving benefits, FiWi networks may face operators and enterprises be unwilling to embrace them because of incurring compromises with security and privacy which may put their business at risk and may result in significant financial losses.

In this paper, we focus on automated social engineering (ASE) attacks over FiWi access networks. Social engineering is the art of exploiting the weakest link of information security systems as well as human factors to manipulate a person or group of people for the purpose of gaining access to sensitive information or systems. Attacks may also involve various kinds of technology, e.g., malware, e-mails, or manipulation of software. Future FiWi broadband access networks will not only provide quad-play services but also integrate applications and services of social networking sites such as Facebook, LinkedIn, Twitter, YouTube, Amazon, and MySpace on the same infrastructure, including additional applications such as medical care, e-governance, e-learning, weather forecasting, and traffic monitoring. As a consequence, social engineering attacks can be automated through these networking sites by means of different communication tools and protocols. According to [3]:

“Much like the current botnets, which are threatening due to their size and network communicating possibilities, the automated social engineering (ASE) bots will be threatening due to the fact that they will know so many people and so much about them. Their threat will lie in abusing the social networks, and not the Internet traffic networks.”

As users put their personal data in SNS, social engineering attacks can be automated. An attacker can use the subscriber's information as well as Internet bots to gather information and perform sophisticated ASE attacks. ASE bots require no human involvement and are scalable, thereby rendering social engineering a cheap and appealing attack [4]. SNS are an attractive platform for ASE attacks as they provide seamless services for a large number of users with a wide range of applications and socio-demographic characteristics. The aim of this paper is to develop and a security architecture for future broadband FiWi access networks that helps secure end users from ASE attacks and transfer the entire security solution to the networking devices such that the security credentials are set automatically during communications.

The remainder of the paper is structured as follows. Section 2 briefly reviews the state-of-the-art of FiWi access networks and discusses their security issues with an emphasis on ASE attacks. Section 3 introduces a holistic approach of ASE attacks over FiWi access networks via SNS. In Section 4, we will describe our proposed security architecture for ASE over FiWi access networks. Section 5 concludes the paper.

2. FIWI ACCESS NETWORKS AND SECURITY ISSUES

The state-of-the-art of FiWi access networks has been recently surveyed in [5]. The survey provides an overview of enabling FiWi technologies and recently proposed FiWi network architectures. Most of the proposed FiWi networks make use of low-cost Ethernet technologies such as IEEE 802.3ah Ethernet passive optical network (EPON) and IEEE 802.11 wireless LAN (WLAN), with a few exceptions deploying also IEEE 802.16 WiMAX. The survey highlights previously addressed challenges and outlines open issues of emerging FiWi networks. Among others, different FiWi network architectures as well as advanced path diversity, wavelength channel assignment, performance monitoring, fault management, load balancing, and reconfiguration techniques to improve the bandwidth efficiency and resilience of FiWi networks have been studied in depth.

Apart from the aforementioned optical and wireless technologies, next-generation FiWi networks will also have to incorporate emerging long term evolution (LTE) cellular and long-reach PON (LR-PON) technologies. LTE is an enabling technology for wireless access networks which helps improve their network throughput, coverage, and operational costs significantly. In comparison with WiMAX, LTE is able to reduce the round-trip latency to 10 milliseconds for both unpaired time division duplexing (TDD) and paired frequency division duplexing (FDD) [6]. Conversely, LR-PON introduces hybrid dense wavelength division multiplexing (DWDM)/time division multiple access (TDMA) techniques accommodating up to 32 different TDMA PONs. A LR-PON aims at supporting up to 16,000 subscribers over distances of up to 100km from a single network service node with 10Gb/s symmetric data rates in both upstream and downstream directions [7].

2.1 Security Issues in FiWi Access Networks

Designing security in wireless networks is a challenge. Among others, key security issues in wireless networks are the shared wireless medium, severe resource constraints, dynamic network topology, reliable and trusted infrastructure, open peer-to-peer network architecture, roaming, handover as well as interference in co-channel and adjacent cells. These issues cause a range of vulnerabilities and threats in wireless networks such as Denial-of-Service (DoS), sniffing, snooping, masquerading, signal jamming, traffic analysis, network injection and partition, message modification, man-in-the-middle, and wardriving attacks [8], [9].

Security issues have also been studied in optical networks considering different scenarios such as in-band-jamming, out-of-band jamming, gain competition, tapping attacks, channel attacks, denial and theft of service, eavesdropping, and masquerading. For detecting and preventing these threats and security holes in optical networks, a variety of authentication and encryption protocols may be used, e.g., Rivest Shamir Algorithm (RSA), Advanced Encryption Standard (AES), and Elliptic Curve Cryptography (ECC) [10], [11].

Until now, security has been mostly studied separately either in wireless or optical networks. No profound research activities have been conducted on security in integrated FiWi networks so far. All aforementioned security issues also apply to FiWi networks. Note, however, that FiWi networks may suffer from a number of specific security threats which can be categorized into terminal security, network security, and channel security. To protect FiWi networks against different threats and provide secure access, a multilayer strategy spanning all network layers is required. Heterogeneous networks in general and FiWi networks in particular introduce security

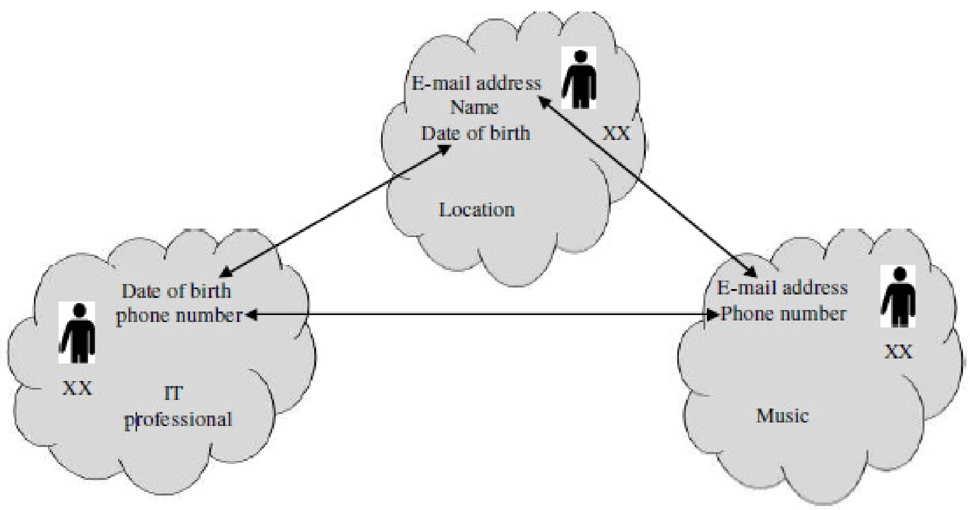

FIGURE 1: Cross-network information aggregation.

issues like mutual authentication, device identification, data integrity, access control, and denial-of-service. Moreover, other challenging issues like efficient call handover, session initiation, dynamic bandwidth allocation, and congestion control are also becoming considerably vital from a network management point of view for heterogeneous networks. Specific security issues that might arise in FiWi networks include first/last mile security (inter-domain security), managing secure moving application sessions, secure context transfer, zero-day vulnerabilities, buffer overflows, structured query language (SQL) injections, separate IP authenticity during each handover, validation of different data rates, and interception. In this paper, we will focus on ASE attacks over FiWi access networks which come in the following three flavors:

ASE attacks over SNS: SNS are becoming increasingly popular. They represent a promising platform for companies to advertise their products to a huge number of users. With the powerful development of search engine techniques, online communities, and user groups, personal information can be disclosed and modified by malicious users. Even though current SNS maintain a certain level of security, they fall short to protect each user's profile privacy. Due to out-of-context information disclosure, in- and cross-network information aggregation, and software bugs it is easy to gather personal information via chatting, spam, Internet bots, malware, data mining, and phishing from SNS. Hence, social engineering attacks may be done automatically through SNS [4]. ASE attacks over SNS may also occur through face recognition, social viruses and worms, and stalking (unwanted attention by individuals and sometimes groups of people to others for harassment and intimidation). Conversely, some other powerful techniques like cross-site scripting (code injection by malicious web users), cyber-bullying and grooming, corporate espionage, and infiltration of networks leading to information leakage, may be used for ASE attacks. For illustration, Figure 1 shows a cross-network information aggregation technique with a significant amount of member overlap across three different social networks based on location, IT professional, and music through common interest, choice, and hobbies. Users of multiple social networks may not want information of different contexts to be mixed up with each other. For instance, in Figure 1 user `XX' provides information such as his or her e-mail address, name, and date of birth in an SNS based on location, whereby the date of birth is shared with another SNS (IT professional). Similarly, the home phone number is available in SNS Music. Given the increasing use of SNS and powerful development of information retrieval processes (interconnection of SNS with Google) it is easy for an attacker to aggregate information from connected sources in order to acquire information related to the privacy of user `XX'.

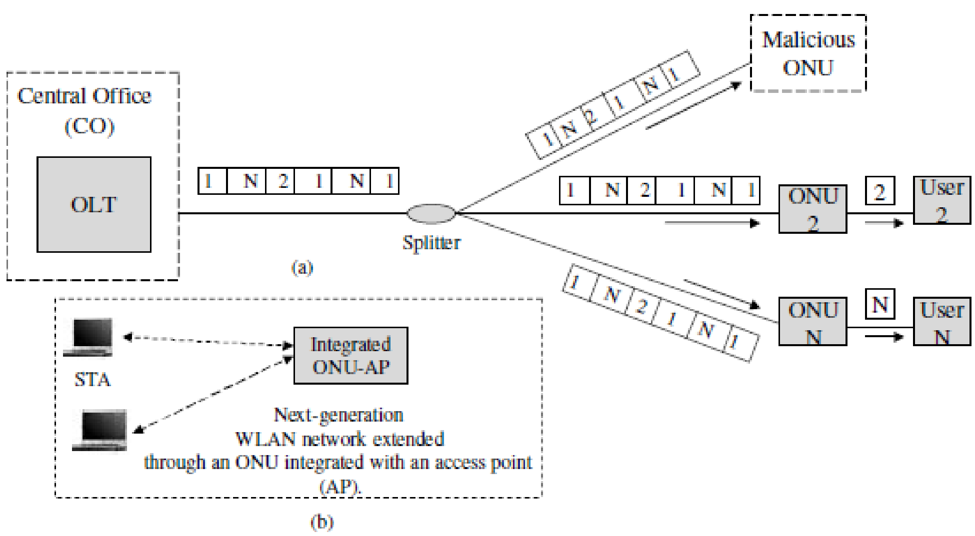

FIGURE 2: Malicious ONU monitors downstream transmissions from OLT to ONUs in a broadcast EPON.

ASE attacks over networking devices: A FiWi access network convergence different optical and wireless technologies. Due to the convergence of different technologies and dissimilar networking protocols, ASE attacks can be launched at FiWi networking devices such as EPON optical network units (ONUs) or WLAN access points (APs). As shown in Figure 2(a), a malicious ONU can analyze all downstream packets coming from the central optical line terminal (OLT) due to the broadcast nature of EPON. Hence, a malicious ONU may gather sensitive network information like logical link identifiers (LLIDs), medium access control (MAC) addresses, and device identities of APs, leading to serious ASE threats to networking devices. A malicious ONU or its attached users may inject malicious code to the networking devices and collect information about the network. Moreover, it may also set up an ASE bot in the network to collect information related to network resources like bandwidth allocation and transmission time. ONUs act as a packet filter to forward packets to authorized users. For example, in Figure 2(a), ONU 2 filters packets intended for user 2, though it receives all packets broadcast by the OLT. Figure 2(b) depicts a FiWi network based on an ONU integrated with a next-generation WLAN AP. Due to the broadcast transmission properties of the AP, the identity of wireless users and AP are vulnerable in an open network with wireless extensions. Moreover, communication channels between wireless station (STA) and integrated ONUs can also be hijacked by malicious users. Hence, network optimization, security credential, and a bandwidth management plan is required at the central office (CO) to eliminate sophisticated ASE attacks.

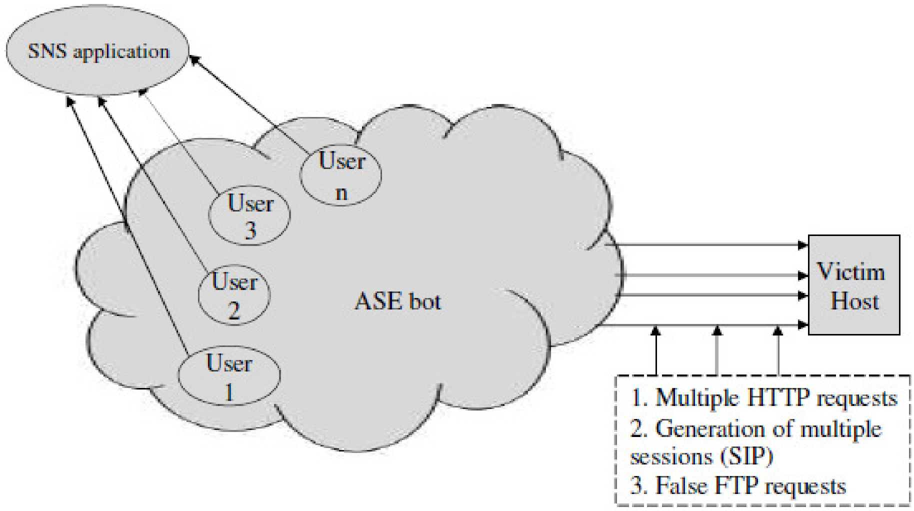

FIGURE 3: Users execute a malicious application in an SNS subsequently generate a series of different requests such as HTTP, FTP, and multiple sessions to target the victim host.

ASE attacks from end users: SNS provide all the essentials needed for the easy deployment of applications. It may happen that a group of malicious users can develop SNS applications such as a quiz, IQ test, or game, and add them to the account. A user who wants to use such a type of application causes a serious security threat. On the other hand, malicious users and groups may create several groups and invite people to join them in order to collect the information required for creating ASE attacks. Moreover, most of the SNS applications can be developed in personal home page (PHP) or Java. Developers may use information such as the name of the application, the IP address of the web server, and submit it to the server. Hackers may manipulate the communication between server and developers by introducing web bugs through this type of page submission. Basic tools for ASE attacks from end users in SNS include the following: (i) ignorance about IT security due to a very large and highly distributed user base; (ii) same application (developing the trust with each other), resource (asking for access to the same resource), or information (the same social interests); (iii) SNS platform attracts users to install unwanted applications; (iv) friendliness, showing confidence in an idea and impersonation; and (v) open gateway for hackers to develop applications to gather information through ASE bots. Figure 3 illustrates how an ASE bot may work in an SNS through multiple images, text files, session initiations, and HTML pages. When multiple users interact with the same applications, the victim host may receive unsolicited requests. These requests are triggered through the SNS. The SNS application used by the users (generated by the Web browser) and local devices execute the application. Hence, when multiple users act through the same application and generate multiple sessions or HTTP requests in the application, they create a malicious SNS application defined as an ASE bot. An AS E bot is depicted in Figure 3, where the cloud illustrates a collection of SNS users browsing a malicious application in the SNS. This causes a series of requests to be generated and directed towards the victim [12].

2.2 ASE over FiWi Access Networks

Figure 4 illustrates the convergence of next-generation EPON with WiMAX/LTE BS for different scenarios [13]. The most intuitive way to integrate EPON and WiMAX/LTE is to use independent architectures where EPON and WiMAX/LTE systems are operated independently by considering a WiMAX/LTE BS a generic user attached to an ONU. The two devices may be interconnected via a common standard interface, e.g., Ethernet. The hybrid ONU-BS architecture is an enhanced approach to integrate an ONU and a WiMAX/LTE BS in a single box (ONU-BS), as illustrated in the lower ONU of Figure 4. The connection-oriented architecture is a more complex convergence approach due to the different transmission properties of WiMAX and LTE. WiMAX is a connection-oriented transmission technology where each service flow is allocated a unique connection ID (CID). In contrast, EPON does not support connections and bandwidth requests are queue-oriented. The OLT allocates bandwidth to each ONU, and then the latter one makes a local allocation of the granted bandwidth to up to eight different priority queues.

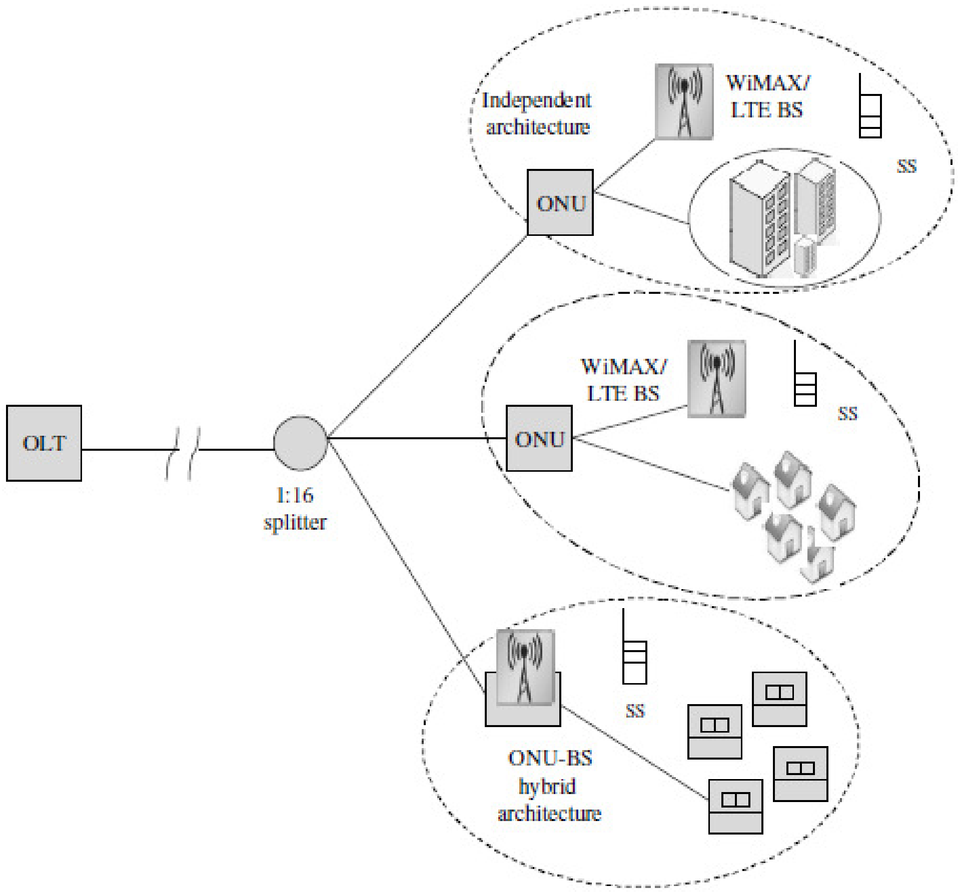

FIGURE 4: Convergence of next-generation EPON and WiMAX/LTE base station (BS) [13].

There are vulnerabilities of ASE attacks for all aforementioned integration processes. In WiMAX/LTE networks, identity theft is a severe threat to unlicensed services supported by WiMAX/LTE. A fake device can use the hardware address of another registered device by intercepting management messages over the air. Once succeeded, an attacker can turn a BS into a malicious BS. A malicious BS can imitate a legitimate BS by hijacking the associated SSs and gather the information about the entire network which poses a serious threat of ASE attacks. In integrated systems, each SS uses the dynamic host configuration protocol (DHCP) to obtain an IP address from the DHCP server, which can be attached to the central OLT or a remote ONU-BS.

The following two packet/frame forwarding techniques have been proposed for integrated EPON-WiMAX/LTE networks [13]: (i) network-layer IP packet routing and (ii) link-layer Ethernet frame switching. There is a range of security threats related to ASE attacks for the two aforementioned packet/frame forwarding techniques. First, the DHCP server should not be located at an insecure location such as the OLT. Usually, the CO maintains the IP addresses of all SSs. An ASE bot (through a malicious ONU) can control the DHCP server due to the lack of authentication of ONUs. Hence, end-to-end security solutions are required to assign IP addresses to SSs from the CO. Moreover, IP packets are sent by the user without encryption to the access router. Hence, other SSs can falsify the identity of SSs, resulting in a serious threat of ASE attacks to the entire network. Similarly, due to the loop-back fashion of the network-layer solution, time constraints of accessing networking resources are an important factor for SSs to eliminate the attacks related to ASE.

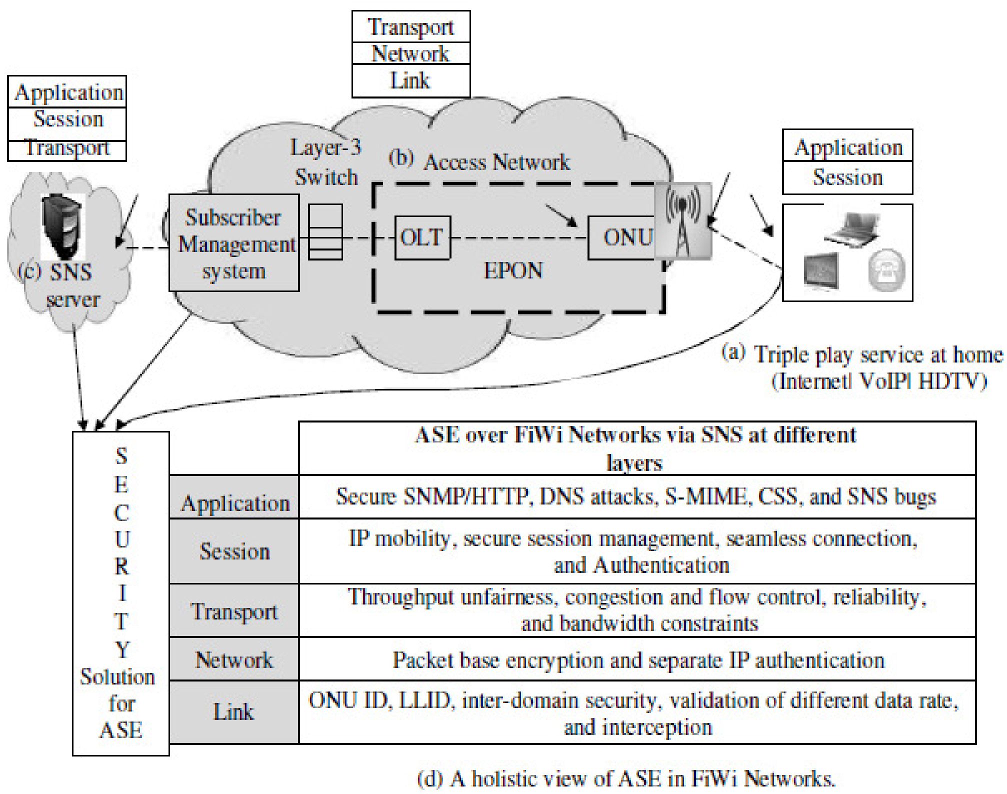

FIGURE 5: A holistic view of ASE attacks over FiWi networks via SNS.

Conversely, in the link-layer solution, Ethernet frame and IP packet downstream transmissions without encryption cause a security threat to SSs and integrated ONU-BSs. In this solution, Ethernet frames are switched based on MAC addresses. Therefore, the coherence and synchronization between two access routers (associated with OLT and ONU-BS) are required, otherwise MAC addresses may be falsified. Due to the different traffic patterns (in-microcell/out-microcell) of SSs, ONU-BSs need to prioritize traffic instantly to allow an access router to provide access to network recourses. Consequently, a malicious SS/ONU-BS can hijack the traffic pattern in order to access the network. Moreover, in both scenarios, IP and MAC addresses are sent across a public network, causing insecure communication for networking devices (Ethernet bridge and access router) to maintain an appropriate routing table (IP addresses and MAC addresses), to manage network resources, and to ensure security credentials for authorized users, ONUs, and BSs.

3. A HOLISTIC VIEW OF ASE ATTACKS OVER FIWI ACCESS NETWORKS VIA SNS

A holistic approach against ASE attacks over FiWi access networks carried out through SNS is shown in Figure 5. This approach aims at improving the performance of FiWi access networks with respect to security, longevity, optimization, and connectivity. Figure 5 (d) depicts a variety of security holes and vulnerabilities in FiWi networks occurring at from different networking layers. Security has to be ensured at all the layers of the protocol stack while the cost for ensuring security should not surpass the assessed security risk. A holistic network are shown in Figure 5: (a) home network for end users and mobile subscribers, (b) access network (convergence of EPON with WiMAX/LTE BS), and (c) SNS platform. The failure of inter-domain security and link-level identification may seriously affect the entire network to gather the information, possibly resulting in sophisticated ASE attacks.

Usually, these failures occur at network gateways. Hence, four main gateways (home users, ONU-BSs, transmission between OLT and ONU-BSs, and SNS) have been marked with an arrow. Let us assume that a traffic stream, shown by dotted lines, is generated by the SNS server, traverses core and EPON networks, and finally reaches the end users. In FiWi networks, per-flow QoS cannot be maintained in the core. This function must be performed at the edge of the network near the end users, e.g., EPON. We propose a layer-3 switch to carry best-effort web access traffic originating from SNS. It will ensure the per-flow serv ice level agreement (SLA) enforcement and prioritizing (high-bandwidth flows, traffic type, and congestions) the tr affic of the subscriber management system.

In Figure 5, the SNS server uses hypertext transfer protocol (HTTP) cookies and hidden form fields to maintain the authentication, access control, and authorization state after successful login to an SNS. The HTTP cookies contain session information while the hidden form fields ensure that forms are submitted by users and are protected against cross-site request forgery attacks. Since the hidden form values are partly created by JavaScript, this authentication method also blocks bots that are not JavaScript compatible. Third-party applications represent an additional attack which could be exploited by an ASE bot for malicious actions, e.g., to launch distributed DoS attacks or to gather personal information about future victims [12], [14], involving security issues like authorization, access control, and confidentiality for ASE attacks over SNS.

Figure 5 also shows various attacks at different networking layers related to ASE over FiWi networks. For example, at the application layer, in DNS attacks related to ASE an attacker exploits cross-site request forgery (CSRF) vulnerability by triggering a victim to visit a malicious page (SNS). The page will consist of specially crafted `xslt' requests designed to perform some action on the attacker's behalf. An attacker can exploit this to perform DNS poisoning attacks through the `NAME' and `ADD' parameters. Similarly, at the link layer, LLIDs need to be protected in all frames from being listened or attacked by a malicious user at an EPON downstream link. Moreover, separate IP authentication in the upstream direction (from end users to integrated ONU-BS) will also necessary to be protected.

Most of the SNS have implemented automated mechanisms to detect abusive behavior during communications. However, these mechanisms are not enough to provide security. Therefore, the subscriber management system needs to report about abusive behavior to the layer-3 switch in order to block traffic immediately. Once a possible abuse of an SNS feature is detected users are warned and if they don't adapt their using habits their accounts get permanently disabled. Security metrics that might detect an ASE bot are as follows: (i) fake names in profile, e.g., nicknames, (ii) exceeded rate limits to join or invite people in groups, messages on walls and groups, messages sent to other users, new friends, and accessed profiles, (iii) duplicate t ext in multiple messages to detect spam messages, and (iv) web scraping such as browsing speed [4].

4. SECURITY ARCHITECTURE FOR ASE

We propose a new security architecture for FiWi networks, in order to guarantee secure communications in access networks and avoid ASE attacks. This architecture is proposed only for the access network (OLT to ONU-BS) of Figure 5. The architecture ensures secure communication in both upstream and downstream for each frame sent and received by the OLT and ONU-BS, respectively. Figure 6 depicts the four different modules of our proposed architecture: (a) Encryption Module, (b) Packet, Frame, and Secure payload (PFS) Module, (c) Traffic Analyzer and Confidentiality, Integrity, and Authentication (CIA) Module, and (d) Controlling Module. Figure 6 illustrates in greater detail how frames are managed within the access network in a secure way. The functionalities of each module are as follows:

Encryption Module: The encryption module consists of a parameter set, key management & generation, and link management interface (LMI). The parameter set and key management & generation will set the parameters, e.g., initiation vector (IV), AUTH code, and keys for insecure frames. The AUTH code will be generated by the LMI, including negotiation of the parameter set and key generation for each frame. A statistical report will be stored to compare the transmission time between upstream and downstream traffic for future authentication. *PFS Module*: The PFS module is a combination of payload, frame framer, and packet multiplexer/de-multiplexer (MUX/DMUX). A frame framer encapsulates data received from the advanced encryption standard in counter-mode (AES-CTR) with a MAC header. Subsequently, every frame will be checked for its identity using the CIA module and is scheduled by the downlink (DL) scheduler for transmission to avoid congestion in the network. *Traffic Analyzer & CIA Module* : The traffic analyzer & CIA module is an integration of different modules such as traffic auditing & management module, fault and alarm management module, authentication and access control module. The traffic auditing module monitors the transmission of different frames between OLT and ONU-BS. If any abusive traffic travels across the access network, it will be immediately report to the fault management module in order to discard the frame. The authentication and access control module checks the fundamental security parameters like confidentiality, integrity, authentication, and access control on a per-frame basis in both upstream and downstream directions. *Controlling Module:* The controlling module is a combination of OLT& ONU-BS controller, CPU, and mapping unit. This module is responsible for blocking abusive traffic, checking the security credentials of users, traffic going to encoder or coming from decoder, man aging the functionalities of other modules, and monitoring the control messages generated by ONU-BS and OLT.

Beside this, the frame encoder/decoder delivers/receives the payload to/from the advanced encryption standard AES-CTR module. AES-CTR generates a unique per-frame value for each payload and communicates this value to the frame MUX/DMUX for upstream or downstream transmissions. It checks the identity of each ONU-BS or subscriber's transmission through the identity check module. The same IV and key combination must not be used more than once. The IV used here is 64 bits long (8-octets) with a key size of 128 bits (10 rounds). It also receives an instruction for AES-CTR from the parameter set in order to perform authenticated encryption. This approach can protect against eavesdropping attacks by deploying encrypted LLID header for each logical link, whereby the header is encrypted separately with a different IV for each encrypted packet prior to upstream transmission. Hence, attackers are unable to obtain the MAC address or LLID and to masquerade as another ONU.

Upon the reception of frames, the frame analyzer examines them, and forwards insecure fames for encryption on the basis of their LLID. The transmission time, AUTH code value, and key parameters are stored as a statistical report, thus guaranteeing secure transmission.

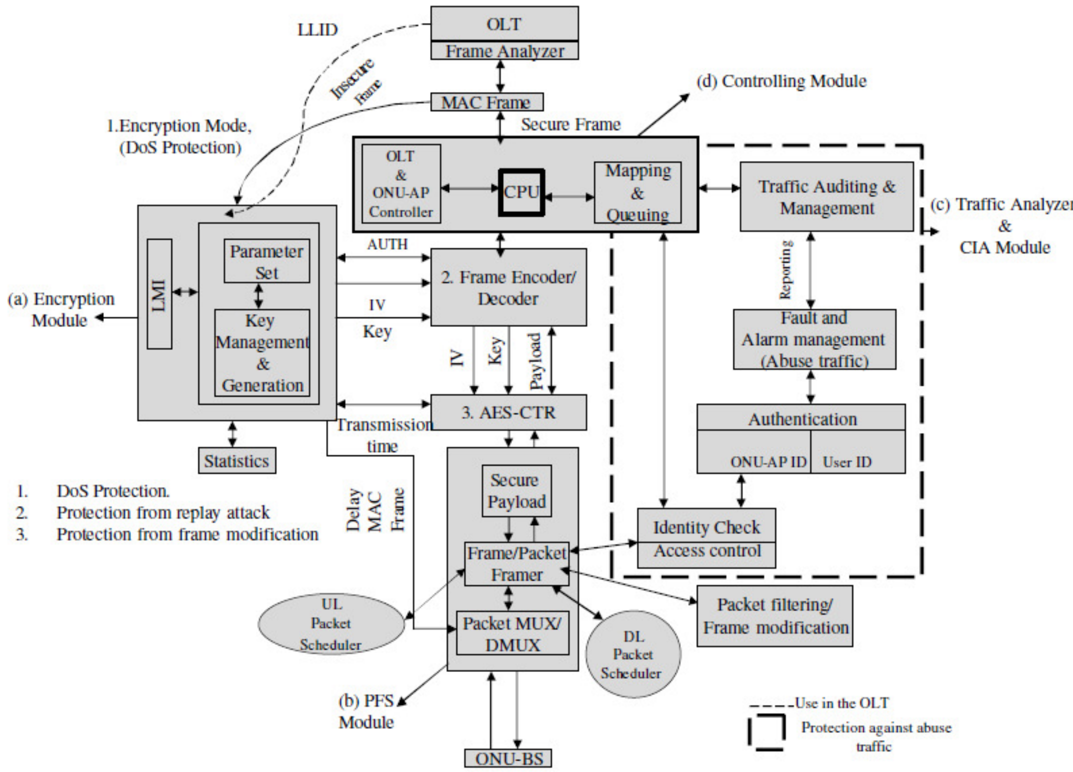

FIGURE 6: Security architecture for ASE over FiWi networks.

Our proposed security architecture ensure protection against ASE attacks in the following way: 1) The architecture protects against eavesdropping attacks by using an encrypted LLID header for each logical link. Hence, attackers cannot obtain the MAC address or LLID. 2) During transmission, each transmission window will be checked through the AUTH code of the previous statistical report. As a result, primary resources (transmission time and bandwidth) are protected from DoS attacks, which in turn reduces the risk of ASE attacks. Moreover, attackers cannot inject automatic malicious code in upstream transmission due to the use of a separate AUTH code, IV, and transmission time for each window. 3) Attackers cannot set up an ASE bot in the access network due to the link level identity and per-frame based access control. Furthermore, all traffic in upstream and downstream direction will be audited to reduce the vulnerabilities of abusive communications. Hence, the controlling module obtains a complete traffic scenario from the traffic management system in order to take action immediately. 4) The IP addresses from the DHCP sever (associated with the CO) are transmitted separately after assigning an LLID to each ONU. This mitigates the risk of IP spoofing. Moreover, all the packets undergo a filtering process in the downstream direction to assure the subscriber's identity.

5. CONCLUSION

FiWi access networks hold great promise to support future broadband services and applications on the same infrastructure. Similarly, SNS are a promising approach to merge end-user applications. However, security is a severe obstacle in FiWi networks and SNS because of automatic engineering and powerful information retrieving tools in today's networks. We discussed ASE attacks over FiWi networks and explained how they may occur at different networking layers. We proposed a security architecture following a multi-layer strategy that examines the traffic in both directions and extracts abusive traffic of applications run over SNS. Several fundamental security issues like CIA and access control are addressed by our proposed security architecture for FiWi access networks.

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