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# A Review on Existing Active Noise Reduction for Industrial HVAC system

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**Abstract -** The existing industrial active noise reduction (ANR) for heating ventilating and air conditioning (HVAC) system has increased in terms of demand. It is a concern due to the amount of noise generated by industrial HVAC system which can be a problem to the surrounding, where noise pollution is always taken into consideration for healthier environment. In this paper, the industrial HVAC system is appraised based on implementation of the system, placement of sensor and actuators in addition there is also review on algorithms. Moreover, the active noise reduction system is introduced to reduce the lower frequency noise range, this helps in reducing the noise pollution created by the industrial HVAC system. Besides, the placement of sensor and actuators plays a role in determining the suitable distance in achieving best noise reduction position. Furthermore, an evaluation is done on Filtered-XLMS and Kalman Filter active noise cancellation algorithm, the results show that the FxLMS algorithm has much better performance rate compared to Kalman filter in terms of convergence. Lastly, multiple ways of implementing the ANR system is also evaluated which indicates that there are many methods in reducing the noise pollution.

**Index Terms -** Active noise reduction (ANR), Heating ventilating and air conditioning (HVAC), Filtered least mean squared (FxLMS) filter, Kalman filter

## 1. Introduction

In this recent era of technology, the industrial companies have increased the manufacturing of the Heating, Ventilating, and Air Conditioning (HVAC) system. The HVAC system assists in cooling and heating the temperature in a room depending on a specific location where the system is placed. The the air-conditioning system comprises seven different processes which are heating, cooling, humidifying, dehumidifying, cleaning, ventilating and air movement, therefore the importance and necessities varies differently (Lopes, Gerald & Piedade, 2015). The usage of HVAC system is wide and is seen to be used in offices, household or even factories. The HVAC system creates an acoustical (noise) environment which affects the rooms surrounding. With the growth of the industrial tools, the noise problem has been promptly increasing. The conventional method used in reducing the noise is via passive noise reduction such as mechanical barriers, enclosures etc. Noises are constituted in different frequency range, the passive noise reduction eliminates in the range of frequency between 4 kHz to 10 kHz but unable to effectively cancel the lower frequency noise of less than 4 kHz because of its unrealistic size of barrier required for noise reduction (Kasbekar, Wisler & Panahi, 2011). The size of the barrier required for noise reduction can be re-evaluated where the thickness of the material can be increased because the low frequency has long wavelengths, but the material will be costly and impractical to implement (Deveneni, Panahi & Kasbekar, 2011).

Therefore, active noise control (ANC) is introduced to control the lower frequency noise effectively. The best way to define ANC is to destructively interfere with undesirable noise with generated secondary sound signal (Rajesh, Jeevamalar & Jancirani, 2012). The ANC is basically a system which assist in removing the undesirable noise coming from the surrounding.

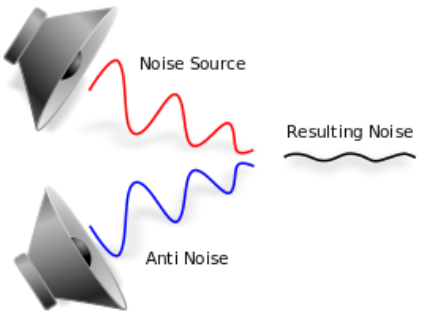


**Figure 1**: Active Noise Cancellation (Swain, 2013).

Figure 1 shows how the active noise cancellation works, where the noise source is represented with a red sine wave line and the anti-noise is represented with blue wave line. When both noises are colliding with each other it results to the minimal wave line which is represented in black. Fundamentally, before the anti-noise is generated, there is a process for computation, where a sensor will identify the noise source, then send it to the signal for a calculation which creates the anti-noise wave in an opposite phase of the noise source signal, then the anti-noise is projected using the loudspeaker to control the undesirable noise source signal. The ANC system cannot really produce a pin drop silence but it reduces to noise to a substantial amount. Thus, ANC system is best suited to be used in creating a more eco-friendly HVAC system. Moreover, it is also preferred that the efficiency of the system to be increased which allows to have a better current and power saving for the HVAC system.

## 2. Implementation of the system

The application of the ANR system here was studied based on three different papers, which basically evaluates the implementation for the ANC system using different approach to help in reducing the noise pollution. Where, in (Devineni, Panahi & Kasbekar, 2011) discussed the methods and algorithms applied is the Feedback ANC and Multiple Input & Multiple Output Period Aware Linear Prediction (MIMO-PALP), it is applied for the MIMO structure which enables a bigger and effective cancelling zone at the surrounding of the compressor surface and the results attained were compared between Noise Attenuation Level of MIMO PALP and Feedback ANC, this is to determine the performance and the MIMO Feedback ANC has a better performance compared to MIMO PALP.

Khan et al., proposed a system based on Virtual Instrument in Reality (VISIR) concept using National Instruments (NI) PXI system which concern the multi-channel measurement and control of the sound field. The approach proposed by the authors is a more comprehensive analysis method for studying the properties of the acoustic modes inside the air ducts in order to achieve better results (Khan et al., 2014).

In (Wisler & Panahi, 2013), the analyses and design of a real time active noise control system for cancelling the acoustic noise generated by an HVAC unit within a 3-dimensional enclosure, where the author used Open Media Application Platform as a controller with a feedback ANC algorithm programmed to it, it could achieve a stable and consistent attenuation of the noise from a commercially available HVAC unit in excess of 14 decibels.

## 3. Placement of Sensor & Actuators

The various position of sensor and actuators can be a great factor in reducing the noise in industrial HVAC system, therefore an evaluation is done on the placement of sensor and actuators. As proposed by Jung et al., a 2x2x2 multi-channel active noise control (ANC) technique is used for the active noise barriers (ANB), where the application is then placed at numerous location which applies a single-channel FXLMS to attain the best noise reduction performance, the outcome of the application is based on two different scenario where one application is tested for multi-frequency tone noise source and another is for an air compressor, Table 1 shows the results for the second scenario, which concludes that the closer the placing of the ANB the better the performance of ANC and improved noise reduction (Jung et al., 2014). Figure 2 shows the ANRS schematic block diagram and structure.

**Table 1**: The noise reduction performance at three different distance (Jung et al., 2014).

| Distance / Condition | 0.1m | 1m | 2m |
|---|---|---|---|
| ANC on (dB) | 54.3 | 52.8 | 53.9 |
| ANC off (dB) | 63.8 | 57.9 | 57.4 |
| Noise reduction (dB) | 9.5 | 5.1 | 3.5 |

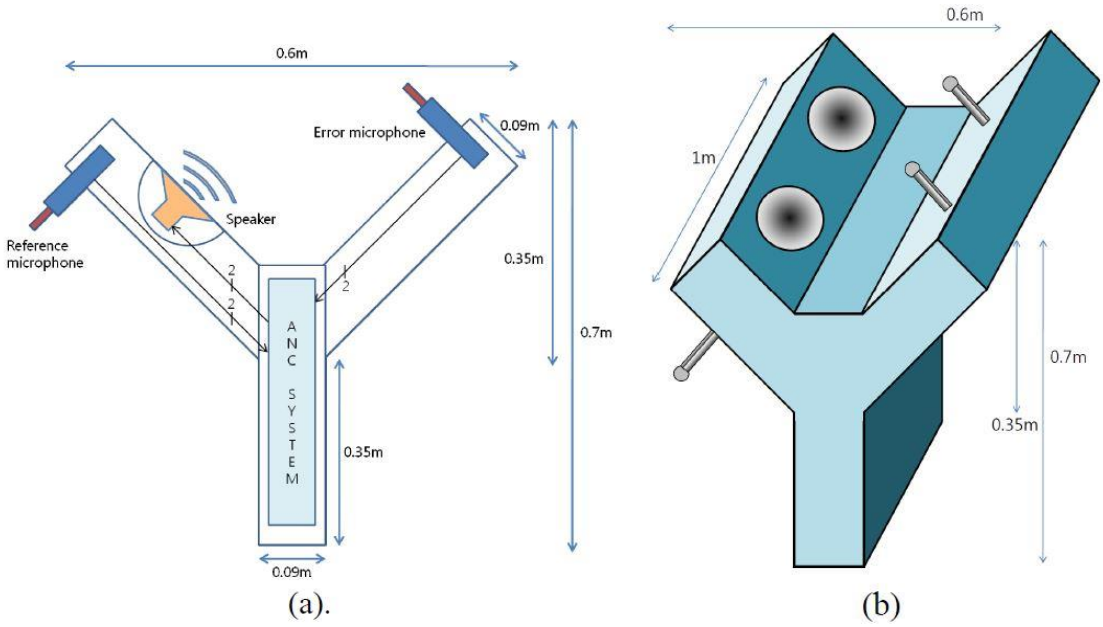


**Figure 2**: (a) Schematic block diagram of ANRS, (b) The structure of ANRS (Jung et al., 2014).

The available techniques that aims at the displacement of error microphone in ANC system was discussed by (Sheth & Ardekani, 2015). The author conducted a comparison about the various types of displacement, with three different types of approach towards the remote ANC, involving the moving microphone, remote ANC and virtual microphone, the conclusion from this approach was that numerous technique has its own advantages and limitations in creating an efficient quite zones by using ANC.

## 4. Algorithms

The comparison of FXLMS and Kalman filter is assessed in this paper. Using a soft threshold based approach on FXLMS algorithm is proposed by authors, MATLAB simulation is done to compare the convergence rate and stability of modified FXLMS and Akthar's algorithm, the reason of using soft thresholding is to enhance the robustness of the Sun's algorithm, the outcome showed that when large amplitude of impulse noise is present, the proposed algorithm improves the convergence rate and its stability (Saravanan & Santhiyakumari, 2015).

According to (Ardekani & Abdulla, 2011) a simple configuration for realization of ANC system is presented which shows how the silence zone is created, it is distributed to five fragments which are ANC physical mechanism, digital electronic control system, secondary path constraint, reference signal measurement constraint and adjustment of ANC controller. The authors also revised the adaptive ANC where it can be simply adjusted to a system identification framework without having the knowledge of the primary and secondary path. According to the research, the FXLMS algorithm is considered to be a vital adaption algorithm in ANC where it is usually considered just to evade mathematical difficulties.

In (Gaur & Gupta, 2016) analyses two parameter which is the improvement in FXLMS algorithm and second is application based review. Feed forward and feedback are the two basic approach for ANC system, the FXLMS algorithm and its application is done based on review which is shown in **Table 2**, where it discussed the improvement of the algorithms based on convergence rate, complexity, etc.

**Table 2**: Summary on Review of FxLMS Algorithm (Gaur & Gupta, 2016).

| Summary No. | Algorithm | Findings |
|---|---|---|
| 1 | FxLMS | Simple computation and convergence slower than conventional LMS |
| 2 | MFxLMS | Convergence better than FxLMS but involves heavy computation. |

| | | |
|---|---|---|
| 3 | MFxLMS1 and MFxLMS2 | Convergence is better than FxLMS (equal to MFxLMS) but computation is lesser than MFxLMS |
| 4 | CFxLMS | Developed for broadband ANC. Here weights of filter are given specific upper and lower bound. Convergence rate has increased. |
| 5 | Variable threshold based FxLMS | Convergence rate has increased with little increase in computation |
| 6 | Convex combination based FxLMS | Convergence rate is high but with heavy computation, since it involves parallel combinations |
| 7 | VSS FxLMS | Developed for Narrow Band ANC, convergence rate has increased (nearly equal to FxRLS) with little computations. Good for both stationary and non-stationary noise environment. Cost and computation complexity lies |
| 8 | Data reusability based FxLMS | Used for impulse noise, it normalizes step size and so improves convergence rate |
| 9 | VSS FxLMS with variable tap length | Maintains good convergence rate even in case of long tap length applications |
| 10 | FxWLMS & FxLMLS | Developed for ANC application to hearing aid and found effective in feedback cancellation in presence of outliers. |

Two analysis is done for Kalman Filter. The paper in (Gabrea, 2012) researches speech signal corrupted by an additive noise for processing where autoregressive (AR) is introduced as a way to overcome corrupted speech signals. According to the author, an algorithm for minimal realization of the model was proposed, by minimizing the mean squared error in the approximation of the speech signal by Kalman Filtering, outcome of this investigation is that the effectiveness of this method is tested using natural speech signal sampled at the frequency of 8kHz corrupted by a Gaussian white noise.

Another Kalman Filter paper was researched on an adaption of the KF to multi-channel ANC was done, the authors proposed an algorithm based on Kalman filter with a random walk space state model (Lopes, Gerald & Piedade, 2015). According to the author, MFx Multi-channel Kalman (MFxMK) comes from the combination of MFx structure with Kalman Filter, this algorithm is less complex to singular or close to singular autocorrelation matrices than the Recursive Least Square and its' results. However, it circulates the covariance matrix of the state approximation.

## 5. Conclusion

This paper conducted a review on active noise reduction for industrial HVAC system, where the implementation of the system, placement of sensor and actuators and algorithms is assessed. And based on this review, future works are taken into consideration in enhancing the ANR system to achieve the best performance for the ANR system for industrial HVAC system, which is also helps in keeping a healthier and noise pollution free environment. Therefore, the implementation of the system can be a standalone ANR system which can be easily implemented into the industrial HVAC system, the placement of sensor and actuators determines the best position for microphone and speakers to be placed in the industrial HVAC to achieve the best noise reduction and the algorithm will determine the performance of the ANR process. In conclusion, future recommendation for the ANR system could be implemented and approached using FXLMS algorithm and raspberry pi.

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