# Enhancing Formation Control of Multi Agent Systems Using Ann Based Technique

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## ABSTRACT

The persistent power failure that paralyzed business activities were caused by these factors that could not attain threshold, Inter-agent spacing error (RMS), Maximum formation shape error, Relative position estimation error ,Formation centroid tracking error , Relative velocity mismatch , Formation convergence time , Communication latency and Energy consumption deviation . This constant power failure observed in the country led to introduction of enhancing formation control of multi agent systems using ANN based technique. To perfectly achieve this, it was done in this manner, formation control of multi agent systems was characterized and the causes of poor formation control of multi agent systems was established and a conventional SIMULINK model for formation control of multi agent systems was designed. Then ANN was trained in the causes of poor formation control of multi agent systems for an effective reduction of the causes of poor formation control of multi agent systems and an algorithm was developed to implement the process. However, a SIMULINK model for enhancing formation control of multi agent systems using ANN based technique was designed and the results obtained were validated and justified. The results obtained were the conventional Inter-agent spacing error (RMS) that causes poor formation control of multi agent systems was 0.4 m. On the other hand, when ANN based technique was integrated into the system, it automatically changed 0.2 m. and the conventional Energy consumption deviation that causes poor formation control of multi agent systems was 27%. Meanwhile, when ANN based technique was integrated into the system, it drastically reduced to 20 %.Finally, with these results obtained the percentage enhancement formation control of multi agent systems when an ANN was integrated in to it was7%.

**Keywords:** enhancing, formation, control, multi agent, systems, ANN based, technique

## INTRODUCTION

Multi-Agent Systems (MAS) have become an important area of research in control engineering, robotics, artificial intelligence, and autonomous systems due to their ability to perform complex tasks through cooperation among multiple intelligent agents. A multi-agent system consists of multiple autonomous entities that interact and coordinate with one another to achieve common objectives that may be difficult or impossible for a single agent to accomplish independently (Olfati-Saber et al., 2007). Applications of multi-agent systems include autonomous vehicle platooning, unmanned aerial vehicle (UAV) swarms, robotic exploration, environmental monitoring, military surveillance, and intelligent transportation systems. One of the fundamental challenges in multi-agent systems is formation control, which refers to the coordination of multiple agents to maintain a desired geometric arrangement while moving collectively toward a common goal. Effective formation control ensures that agents maintain specific relative positions and distances despite disturbances, environmental uncertainties, communication delays, and dynamic changes in operating conditions (Ren & Beard, 2008). The ability to sustain stable formations is critical in applications such as search-and-rescue operations, cooperative transportation, and swarm robotics, where coordinated movement directly influences system performance and mission success. Traditional formation control approaches, including leader-follower, behavior-based, virtual

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structure, and graph-theoretic methods, have demonstrated considerable success in coordinating multiple agents (Fax & Murray, 2004). However, these conventional techniques often rely on accurate mathematical models of agent dynamics and predefined control parameters. In real-world environments, uncertainties such as sensor noise, actuator nonlinearities, external disturbances, and varying communication topologies can significantly degrade the performance of these control methods. Consequently, maintaining robust and adaptive formation control remains a major challenge in modern multi-agent systems. Recent advances in artificial intelligence and machine learning have introduced new opportunities for addressing the limitations of traditional control strategies. Artificial Neural Networks (ANNs), inspired by the structure and functionality of biological neural systems, possess powerful learning and approximation capabilities that enable them to model complex nonlinear relationships and adapt to changing environments (Haykin, 2009). ANNs have been widely applied in prediction, optimization, pattern recognition, and intelligent control systems because of their ability to learn from data and improve performance through experience. In the context of formation control, ANN-based techniques can enhance the adaptability and robustness of multi-agent systems by learning agent dynamics, compensating for uncertainties, and optimizing control actions in real time. Unlike conventional model-based controllers, ANN controllers can approximate unknown nonlinear functions and adjust control parameters dynamically, thereby improving formation accuracy and stability under uncertain operating conditions (Lewis et al., 2013). Furthermore, ANN-based approaches can facilitate decentralized control architectures, where individual agents make intelligent decisions based on local information while maintaining overall formation objectives. The growing complexity of modern autonomous systems has increased the need for intelligent control mechanisms capable of handling nonlinear dynamics and unpredictable environments. Researchers have demonstrated that integrating neural network-based learning with formation control algorithms can improve convergence speed, reduce tracking errors, and enhance fault tolerance in cooperative multi-agent operations (Wang et al., 2020). Despite these advancements, challenges remain in developing ANN-based formation control techniques that are computationally efficient, scalable, and capable of guaranteeing stability in large-scale multi-agent networks. Therefore, this study focuses on enhancing the formation control of multi-agent systems using an Artificial Neural Network-based technique. The study aims to develop an intelligent control framework that improves coordination performance, increases robustness against uncertainties, and maintains stable formations under varying environmental conditions. The findings of this research are expected to contribute to the advancement of intelligent autonomous systems and provide practical solutions for applications requiring reliable cooperative control among multiple agents.

## METHODOLOGY

To characterize and establish the causes of poor formation control of multi agent systems

**Table 1:** characterized and established causes of poor formation control of multi agent systems

| **S/N** | **Formation Control Metric** | **S.I. Unit** | **Good Performance** | **Degraded Performance** | **Poor Formation Control Threshold** | **Conventional causes of Poor Formation Control** of multi agent systems | **Typical Cause(s)** |
|---|---|---|---|---|---|---|---|
| 1 | Inter-agent spacing error (RMS) | m | < 0.05 m | 0.05–0.20 m | > 0.20 m | 0.4 m | Sensor inaccuracies, localization errors, controller gain mismatch |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | Maximum formation shape error | m | < 0.10 m | 0.10–0.50 m | > 0.50 m | 0.8 m | Communication delays, external disturbances |
| 3 | Relative position estimation error | m | < 0.05 m | 0.05–0.15 m | > 0.15 m | 0.18 m | GPS degradation, poor state estimation |
| 4 | Formation centroid tracking error | m | < 0.10 m | 0.10–0.50 m | > 0.50 m | 0.7 m | Navigation errors, leader tracking failure |
| 5 | Relative velocity mismatch | $m \cdot s^{-1}$ | < 0.05 | 0.05–0.20 | > 0.20 | 0.4 $m \cdot s^{-1}$ | Inconsistent actuator response, delayed updates |
| 6 | Formation convergence time | s | < 5 s | 5–15 s | > 15 s | 16 s | Improper controller tuning, insufficient connectivity |
| 7 | Communication latency | s | < 0.02 s | 0.02–0.10 s | > 0.10 s | 0.3 s | Network congestion, limited bandwidth |
| 8 | Energy consumption deviation | J | < 10% deviation | 10–25% | > 25% | 27% | Uneven task allocation, inefficient routing |

To design a conventional SIMULINK model for formation control of multi agent systems

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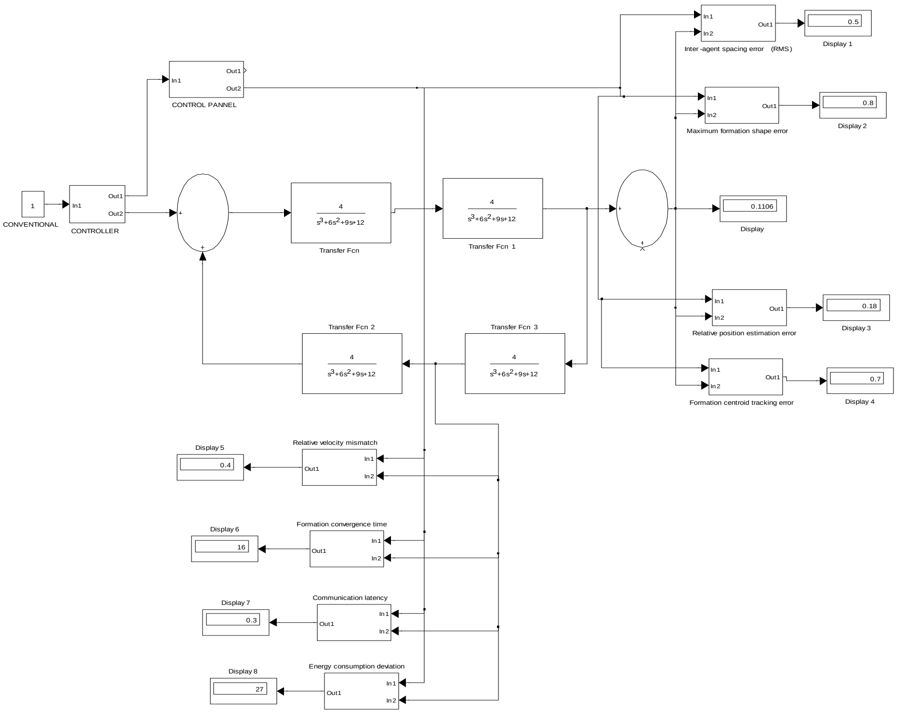


**Fig 1 designed conventional SIMULINK model for formation control of multi agent systems**

The results obtained were as shown in figures 6 and 7

To train ANN in the causes of poor formation control of multi agent systems for an effective reduction of the causes of poor formation control of multi agent systems

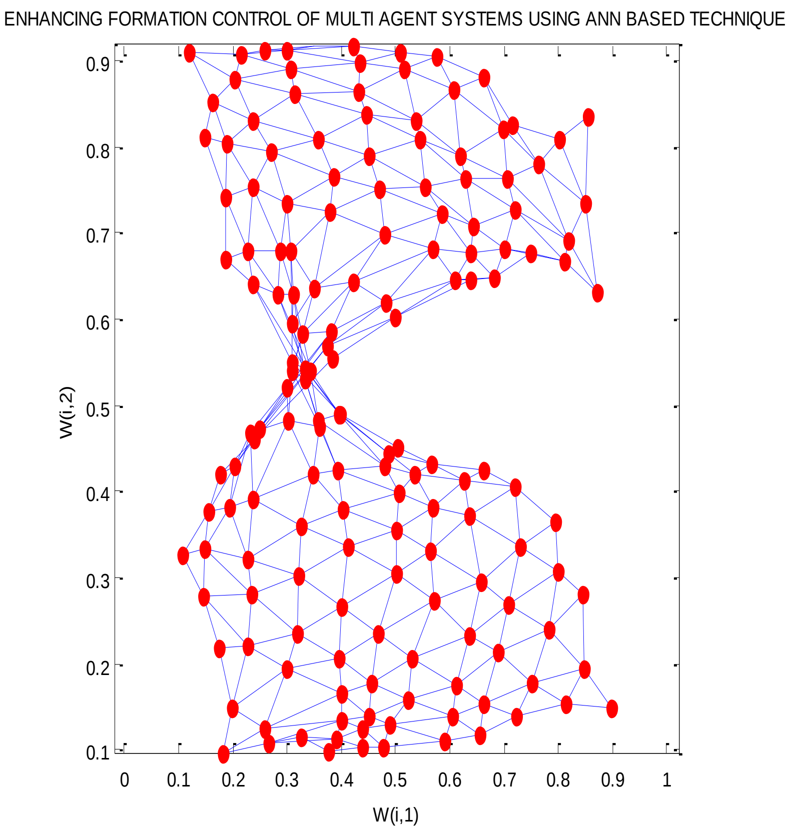


**Fig 2 trained ANN in the causes of poor formation control of multi agent systems for an effective reduction of the causes of poor formation control of multi agent systems**

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In figure 2 ANN was trained twenty times in 8 causes of poor formation control of multi agent systems 20 x 8 = 160 to give hundred and sixty neurons that looked like human brain.

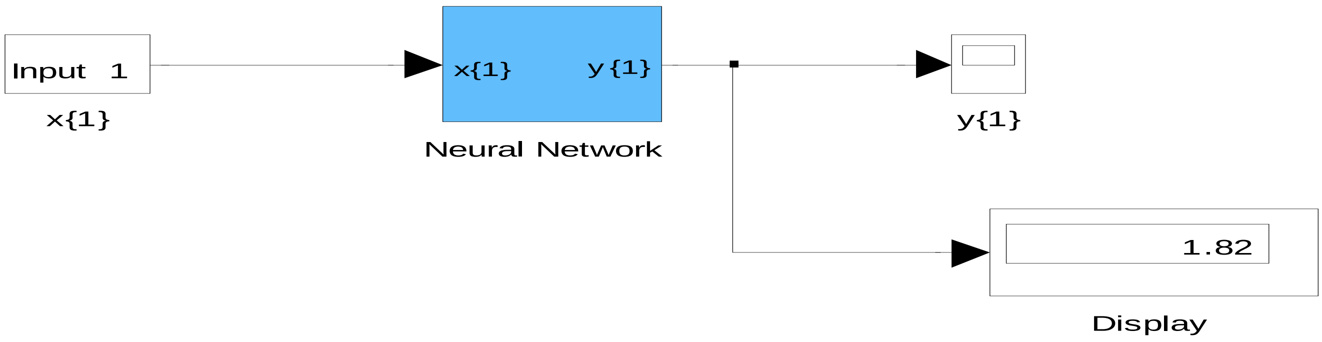


**Fig 3 results obtained in trained ANN in the causes of poor formation control of multi agent systems for an effective reduction of the causes of poor formation control of multi agent systems.**

To develop an algorithm that will implement the process

1.Characterize and establish the causes of poor formation control of multi agent systems

2. Identify Inter-agent spacing error (RMS) that did not attain threshold

3.Identify Maximum formation shape error that did not attain threshold

4. Identify Relative position estimation error that did not attain threshold

5. Identify Formation centroid tracking error that did not attain threshold

6.Identify Relative velocity mismatch that did not attain threshold

7.Identify Formation convergence time that did not attain threshold

8.Identify Communication latency that did not attain threshold

9. Identify Energy consumption deviation that did not attain threshold

10. Design a conventional SIMULINK model for formation control of multi agent systems and integrate 2 through 9.

11. Train ANN in the causes of poor formation control of multi agent systems for an effective reduction of the causes of poor formation control of multi agent systems

12. Integrate 11 into 10.

14.Did causes of poor formation control of multi agent systems reduce and attain threshold when 11 was integrated into 10?

15. IF NO go to 12

16. IF YES go to 17

17. Enhanced formation control of multi agent systems

18.Stop

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18.End

To design a SIMULINK model for enhancing formation control of multi agent systems using ANN based technique

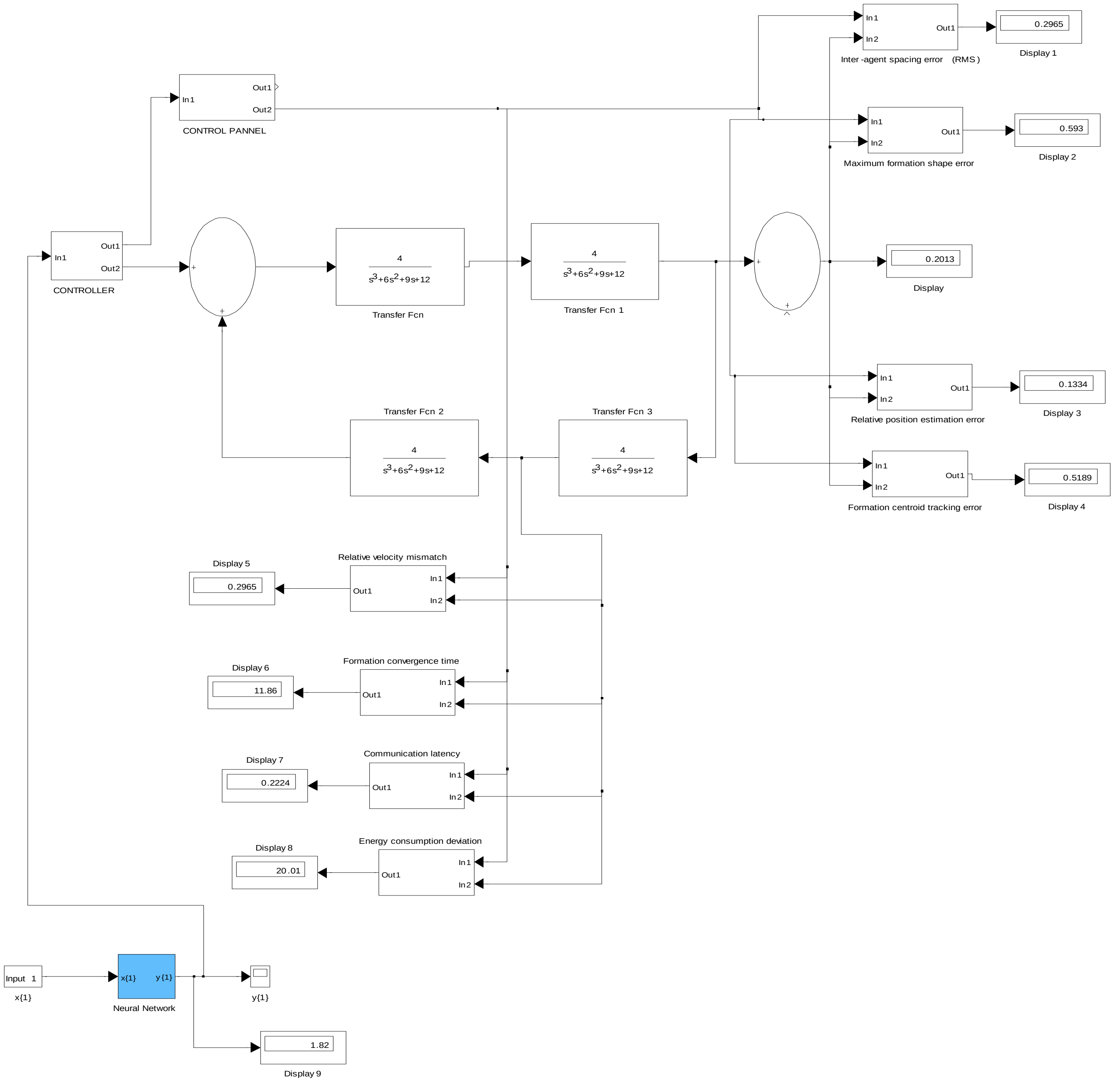


**Fig 4 designed SIMULINK model for enhancing formation control of multi agent systems using ANN based technique**

The results obtained were as shown in 5 and 6.

To validate and justify the percentage improvement in the reduction of causes of poor formation control of multi agent systems with and without ANN based technique

To find percentage improvement in the reduction of Inter-agent spacing error (RMS) causes of poor formation control of multi agent systems with ANN based technique

Conventional Inter-agent spacing error (RMS) =0.4 m

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**ANN** based technique Inter-agent spacing error (RMS)=0.2 m

%improvement in the reduction of Inter-agent spacing error (RMS) causes of poor formation control of multi agent systems with ANN based technique=

Conventional Inter-agent spacing error (RMS)- **ANN** based technique(RMS) x 100%

Conventional Inter-agent spacing error (RMS 1

%improvement in the reduction of Inter-agent spacing error (RMS) causes of poor formation control of multi agent systems with ANN based technique= 0.4 m - 0.2m x 100%

0.4 m 1

%improvement in the reduction of Inter-agent spacing error (RMS) causes of poor formation control of multi agent systems with ANN based technique=50%

To find percentage improvement in the reduction of Energy consumption deviation causes of poor formation control of multi agent systems with ANN based technique

Conventional Energy consumption deviation =27%

**ANN** based technique Energy consumption deviation =20%

%improvement in the reduction of Energy consumption deviation causes of poor formation control of multi agent systems with ANN based technique=

Conventional Energy consumption deviation - **ANN** based technique ECD

%improvement in the reduction of Energy consumption deviation causes of poor formation control of multi agent systems with ANN based technique= 27% - 20%

%improvement in the reduction of Energy consumption deviation causes of poor formation control of multi agent systems with ANN based technique=7%

## RESULT AND CONCLUSION

Table 4 comparison of conventional and ANN based technique Inter-agent spacing error (RMS) that causes poor formation control of multi agent systems(m )

| **Time(months** | Conventional Inter-agent spacing error (RMS) that causes poor formation control of multi agent systems(m ) | ANN based technique Inter-agent spacing error (RMS) that causes poor formation control of multi agent systems(m ) |
|---|---|---|
| **1** | 0.4 | 0.2 |
| **2** | 0.4 | 0.2 |
| **3** | 0.4 | 0.2 |
| **4** | 0.4 | 0.2 |

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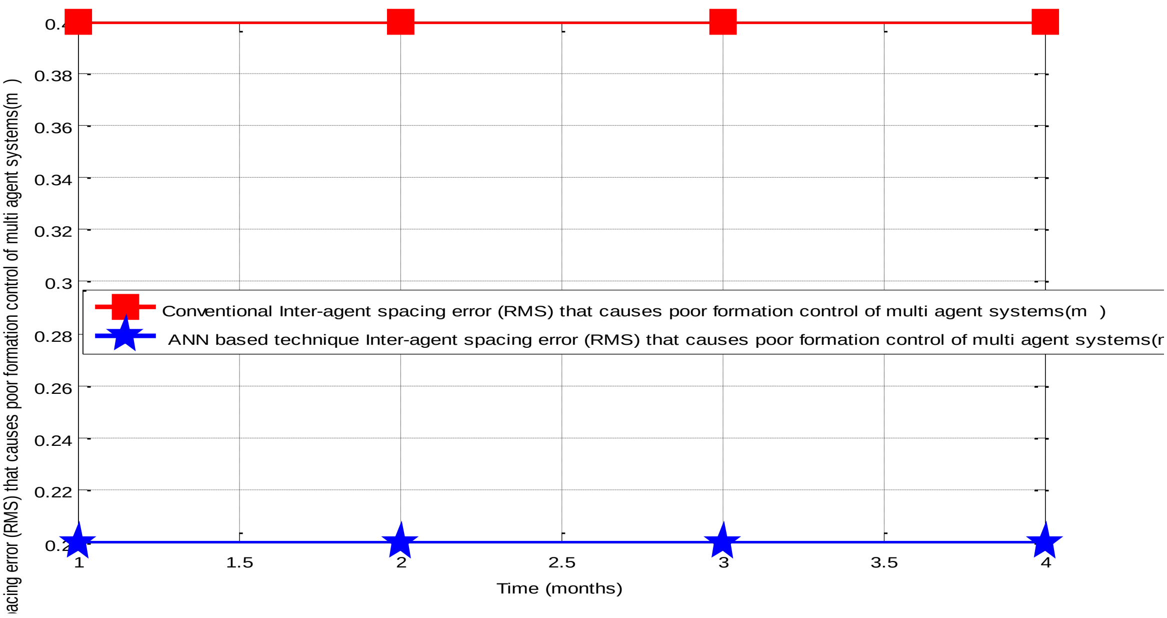


**Fig 5 comparison of conventional and ANN based technique Inter-agent spacing error (RMS) that causes poor formation control of multi agent systems(m )**

The conventional Inter-agent spacing error (RMS) that causes poor formation control of multi agent systems was 0.4 m. On the other hand, when ANN based technique was integrated into the system, it automatically changed 0.2 m.

Table 5 comparison of conventional and ANN based technique Energy consumption deviation that causes poor formation control of multi agent systems(m )

| **Time(months** | Conventional Energy consumption deviation that causes poor formation control of multi agent systems(% ) | ANN based technique Energy consumption deviation that causes poor formation control of multi agent systems(% ) |
|---|---|---|
| **1** | 27 | 20 |
| **2** | 27 | 20 |
| **3** | 27 | 20 |
| **4** | 27 | 20 |

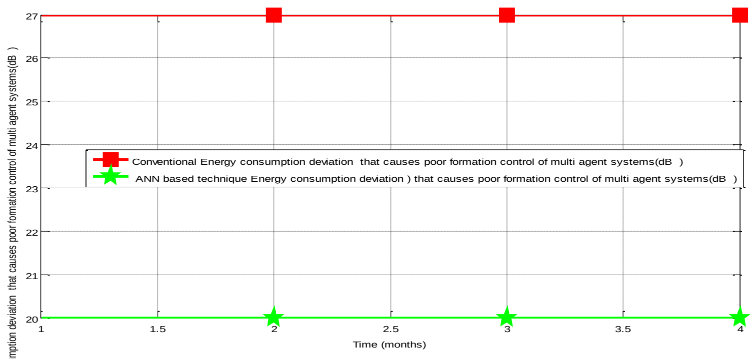


**Fig 6 comparison of conventional and ANN based technique Energy consumption deviation that causes poor formation control of multi agent systems**

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The conventional Energy consumption deviation that causes poor formation control of multi agent systems was 27%. Meanwhile, when ANN based technique was integrated into the system, it drastically reduced to 20 %.Finally, with these results obtained the percentage enhancement formation control of multi agent systems when an ANN was integrated in to it was7%.

## CONCLUSION

The random power failure in the country which had paralyzed business activities was overcame by introducing enhancing formation control of multi agent systems using ANN based technique. To perfectly achieve this, it was done in this manner, formation control of multi agent systems was characterized and the causes of poor formation control of multi agent systems was established and a conventional SIMULINK model for formation control of multi agent systems was designed. Then ANN was trained in the causes of poor formation control of multi agent systems for an effective reduction of the causes of poor formation control of multi agent systems and an algorithm was developed to implement the process. However, a SIMULINK model for enhancing formation control of multi agent systems using ANN based technique was designed and the results obtained were validated and justified. The results obtained were the conventional Inter-agent spacing error (RMS) that causes poor formation control of multi agent systems was 0.4 m. On the other hand, when ANN based technique was integrated into the system, it automatically changed 0.2 m. and the conventional Energy consumption deviation that causes poor formation control of multi agent systems was 27%. Meanwhile, when ANN based technique was integrated into the system, it drastically reduced to 20 %.Finally, with these results obtained the percentage enhancement formation control of multi agent systems when an ANN was integrated in to it was7%.

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