Secure Edge Domination in Neutrosophic Graphs

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Abstract

The concepts of Neutrosophic secure edge domination number and neutrosophic total secure edge domination number in single valued neutrosophic graphs (SVNG) with strong arcs are introduced and analysed in this paper, and some of their properties are studied. The relationship between the neutrosophic secure edge dominance number $\gamma_{nse}(G)$ and its inverse $\gamma^{-1}{}_{nse}(G)$ is presented. The concepts inverse neutrosophic total edge domination set and inverse neutrosophic total edge domination number are also defined. Some of these concepts' properties are investigated.

Keywords: Edge dominating set; Neutrosophic secure edge dominating number; inverse neutrosophic edge domination number.

1. Introduction

Fuzzy sets and fuzzy relations were first developed by L.A. Zadeh [23] in 1965, and Rosenfeld [22] later discovered Zadeh's fuzzy relations on fuzzy sets and first proposed the idea of fuzzy graphs in 1975. Intuitionistic Fuzzy (IF) relations and Intuitionistic Fuzzy Graphs originally proposed by K. T. Atanassov[2] (IFGs). Bipolar fuzzy graphs are discussed and defined by Akram [1], who also developed several operations on them. As a generalisation of the fuzzy graph and the intuitionistic fuzzy graph, Florentin Smarandache et al. [6, 9] developed neutrosophic graphs and single valued neutrosophic graphs (SVNS) as a new dimension of graph theory. The idea of SVNG was developed by Said Broumi et al. [5] who also investigated its elements.

In graph theory and its applications, dominance is a topic of extensive study and application. Initiators of the research of dominating sets in graphs are Ore[17] and Berge[4]. The secure dominance set and the 2-dominating set are presented by Merouane and Chellali[14]. The idea of domination in fuzzy graphs was proposed by A. Somasundaram and S. Somasundaram[20], who also established numerous bounds for the domination number. O.T. Manjusha and M.S. Sunitha introduce "strong dominance" in fuzzy graphs. In intuitionistic fuzzy graphs,

DOI: https://doi.org/10.54216/JNFS.030201
Received: March 12, 2022 Accepted: June 22, 2022

M.G. Karanambigai [11] introduced the secure dominance set, secure total dominating set, 2-secure dominating set, and its domination number.

2. Related Work

Ore and Berge originated the concept of the dominant set in a graph in 1962. S.Arumugam and Velammal [3] introduced the edge dominance. Numerous resource allocation, network routing, and encoding theory problems can be solved using the edge dominant set. Edge dominance and independence in fuzzy graphs are introduced by Nagoorgani et al [16]., who also established several limitations for the edge domination number. The idea of secure edge domination in fuzzy graphs[13] was first developed by V.R. Kulli.

The idea of vertex edge domination in fuzzy graphs was first suggested by Vinod Kumar and Geetharamani[21], who also examined how it functions in these graphs. In intuitionistic fuzzy graphs, M.G. Karanambigai et al[12]. presented secure edge dominating set, secure total edge dominating set, inverse secure dominating set, and its dominance number. The results of numerous investigations [7, 10,15,18] have inspired us to create neutrosophic secure edge domination in neutrosophic fuzzy graphs.

This paper organized as follows. The basic definition and theorems needed for this study discussed in section 3. Section 4 deals with neutrosophic secure edge domination and neutrosophic inverse secure edge domination in neutrosophic graph. The section 5 concludes the paper.

3. Preliminaries

Definition 2.1 [6] A single valued neutrosophic graph (SVN-graph) with underlying set V is defined to be a pair $G = (A, B)$ where

1. The functions $T_A: V \to [0,1]$, $I_A: V \to [0,1]$, and $F_A: V \to [0,1]$, denote the degree of truth-membership, degree of indeterminacy-membership and falsity-membership of the element $v_i \in V$, respectively, and $0 \leq T_A(v_i) + I_A(v_i) + F_A(v_i) \leq 3$ for all $v_i \in V$.
2. The functions $T_B: \mathrm{E} \subseteq \mathrm{V} \times \mathrm{V} \to [0,1]$, $I_B: \mathrm{E} \subseteq \mathrm{V} \times \mathrm{V} \to [0,1]$, and $F_B: \mathrm{E} \subseteq \mathrm{V} \times \mathrm{V} \to [0,1]$ are defined by $T_B(v_i, v_j) \leq T_A(v_i) \wedge T_A(v_j)$, $I_B(v_i, v_j) \geq I_A(v_i) \vee I_A(v_j)$ and $F_B(v_i, v_j) \geq F_A(v_i) \vee \mathrm{F}(v_j)$ denotes the degree of truth-membership, indeterminacy-membership and falsity-membership of the edge $(v_i, v_j) \in E$ respectively, where $0 \leq T_B(v_i, v_j) + I_B(v_i, v_j) + F_B(v_i, v_j) \leq 3$ for all $(v_i, v_j) \in E$ $(\mathrm{i}, \mathrm{j} = 1, 2, \ldots, \mathrm{n})$. We call A the single valued neutrosophic vertex set of V, B the single valued neutrosophic edge set of E, respectively.

Definition 2.2 [6] A partial SVN-subgraph of SVN-graph $G = (A, B)$ is a SVN-graph $H = (V', E')$ such that $V' \subseteq \mathrm{V}$, where $T'_A(v_i) \leq T_A(v_i)$, $I'_A(v_i) \geq I_A(v_i)$, and $F'_A(v_i) \geq F_A(v_i)$ for all $v_i \in V$ and $E' \subseteq \mathrm{E}$, where $T'_B(v_i, v_j) \leq T_B(v_i, v_j)$, $I'_B(v_i, v_j) \geq I_B(v_i, v_j)$, $F'_B(v_i, v_j) \geq F_B(v_i, v_j)$ for all $(v_i, v_j) \in E$.

Definition 2.3 [8] Let $G = (A, B)$ be a SVNG. G is said to be a strong SVNG if

$T_{\mathrm{B}}(u, v) = T_A(u) \wedge T_A(v)$,

$I_{\mathrm{B}}(u, v) = I_A(u) \vee I_A(v)$ and

$F_{\mathrm{B}}(u, v) = F_A(u) \vee F_A(v)$ for every $(u, v) \in E$.

DOI: https://doi.org/10.54216/JNFS.030201
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Definition 2.4 [8] Let $G = (A, B)$ be a SVNG. G is said to be a complete SVNG if

$T_B(u,v) = T_A(u) \wedge T_A(v)$,

$I_B(u,v) = I_A(u) \vee I_A(v)$ and

$F_B(u,v) = F_A(u) \vee F_A(v)$ for every $u, v \in V$.

Definition 2.5 [8] Let $G = (A, B)$ be a SVNG. $\bar{G} = (\bar{A}, \bar{B})$ is the complement of an SVNG if $\bar{A} = A$ and $\bar{B}$ is computed as below.

$\overline{T_B(u,v)} = T_A(u) \wedge T_A(v) - T_B(u,v)$,

$\overline{I_B(u,v)} = I_A(u) \vee I_A(v) - I_B(u,v)$

and $\overline{F_B(u,v)} = F_A(u) \vee F_A(v) - F_B(u,v)$ for every $(u,v) \in E$.

Here, $\overline{T_B(u,v)}, \overline{I_B(u,v)}$ and $\overline{F_B(u,v)}$ denote the true, intermediate, and false membership degree for edge (u,v) of $\bar{G}$.

Definition 2.6 [8] Let $G = (A, B)$ be a SVNG on V, then the neutrosophic vertex cardinality of G is defined by

$$|V| = \sum_{(u,v)\in V} \frac{1 + T_A(u,v) + I_A(u,v) - F_A(u,v)}{2}$$

Definition 2.7 [8] Let $G = (A, B)$ be a SVNG on V, then the neutrosophic edge cardinality of G is defined by

$$|E| = \sum\nolimits_{(u,v)\in E} \frac{1+T_B(u,v)+I_B(u,v)-F_B(u,v)}{2}$$

Definition 2.8 [9] An arc (u, v) of a SVNG G is called strong arc if

$T_B(u,v) = T_A(u) \wedge T_A(v)$,

$I_B(u,v) = I_A(u) \vee I_A(v)$ and

$F_B(u,v) = F_A(u) \vee F_A(v)$.

Definition 2.9[12] Let $G = (A, B)$ be a SVNG. Let e_i and e_j be two adjacent edges of G. We say that e_i dominates e_j if e_i is a strong edge in G.

Definition 2.10 [12] A subset F of E is called an edge dominating set in G if for every e_j ∈ E-S, there exists e_i ∈ F such that e_i dominates e_j.

Definition 2.11[19] An edge dominating set F of an IFG is said to be minimal edge dominating set if no proper subset of F is an edge dominating set.

Definition 2.13 [19] Minimum cardinality among all minimal edge dominating set is called edge domination number of G and is denoted by $\gamma'(G)$.

Definition 2.14 [19] The strong neighbourhood of an edge e_i in an IFG G

Ns$(e_i) = \{e_j \in E(G) | e_j \ is\ strong\ edge\ and\ adjacent\ to\ ei\ in\ G\}$

Theorem 2.15 [10] Every arc in a complete fuzzy graph is a strong arc.

DOI: https://doi.org/10.54216/JNFS.030201
Received: March 12, 2022 Accepted: June 22, 2022

Table 1: Some basic notations

Notation	Meaning
$G = (V, E)$	Fuzzy graph
$G = (A, B)$	Single Valued Neutrosophic Graph (SVNG)
V	Vertex Set
E	Edge set
$T_A(v)$, $I_A(v)$, $F_A(v)$	True membership value, indeterminacy membership value, falsity membership value of the vertex v of $G = (A, B)$
$T_B(u, v)$, $I_B(u, v)$, $F_B(u, v)$	True membership value, indeterminacy membership value, falsity membership value of the edge (u, v) of $G = (A, B)$
$\gamma'_{ned}(G)$	Neutrosophic edge domination number
$\gamma'_{nsed}(G)$	Neutrosophic Secure edge domination number
$\gamma'_{nted}(G)$	Neutrosophic total edge domination number
$\gamma'_{ntsed}(G)$	Neutrosophic total secure edge domination number
$\gamma^{-1}{}_{ned}(G)$	Neutrosophic inverse edge domination number
$\gamma^{-1}{}_{nsed}(G)$	Neutrosophic inverse secure edge domination number
$\gamma^{-1}{}_{nsted}(G)$	Neutrosophic inverse secure total edge domination number

4. Secure Edge Domination in Neutrosophic Graphs

Definition 4.1

Let $G = (A, B)$ of $G^* = (V, E)$ be a single valued neutrosophic graph. An edge subset F of E is called neutrosophic edge dominating set in G, if for every $e \epsilon E - F$, there exists at least one edge $f \epsilon F$ such that f dominates e. The neutrosophic edge domination number of G is minimum cardinality taken over all edge dominating sets of G and is denoted by $\gamma'_{ned}(G)$.

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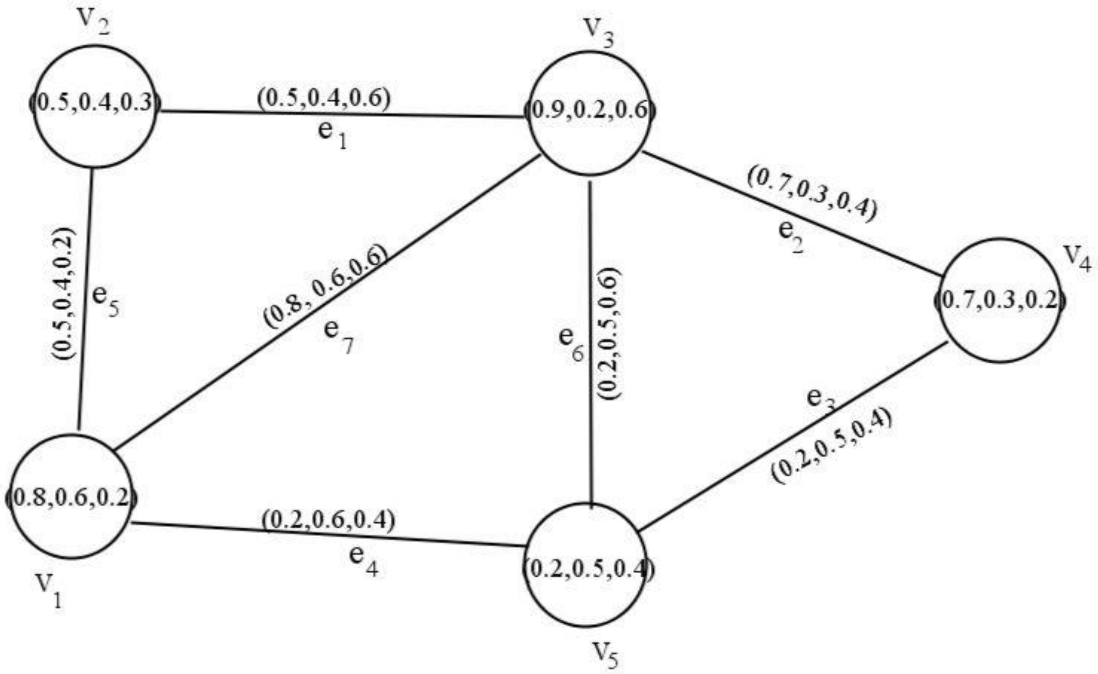

Figure1: Edge Domination in a Single Valued Neutrosophic Graph

Here $\{e_1, e_2, e_3\}$, $\{e_4, e_6, e_7\}$, $\{e_1, e_3, e_5\}$, $\{e_1, e_3\}$, $\{e_1, e_6\}$, are some edge dominating sets of G and $\gamma'_{ned}(G) = 1.2$.

Definition 4.2

Let $G = (A, B)$ of $G^* = (V, E)$ be a single valued neutrosophic graph. A neutrosophic edge dominating set F of E is a neutrosophic secure edge dominating set, if for every $e \epsilon E - F$ is adjacent to an edge $f \epsilon F$ such that $(F - \{f\}) \cup \{e\}$ is an edge dominating set. The neutrosophic secure edge domination number of G is minimum cardinality taken over all secure edge dominating sets of G and is denoted by $\gamma'_{nsed}(G)$.

From figure 1, $\{e_1, e_3, e_4, e_7\}$, $\{e_1, e_3, e_6\}$, $\{e_3, e_4, e_7\}$,$\{e_4, e_6, e_7\}$, $\{e_1, e_3, e_4\}$ are secure edge dominating sets of G and $\gamma'_{sned}(G) = 1.85$.

Definition 4.3

Let $G = (A, B)$ of $G^* = (V, E)$ be a single valued neutrosophic graph.

A neutrosophic edge dominating set F of E is called a neutrosophic edge total dominating set, if the subgraph $<$ F $>$ induced by F is strongly connected. The neutrosophic total edge domination number of G is minimum cardinality taken over all total edge dominating sets of G and is denoted by $\gamma'_{nted}(G)$.

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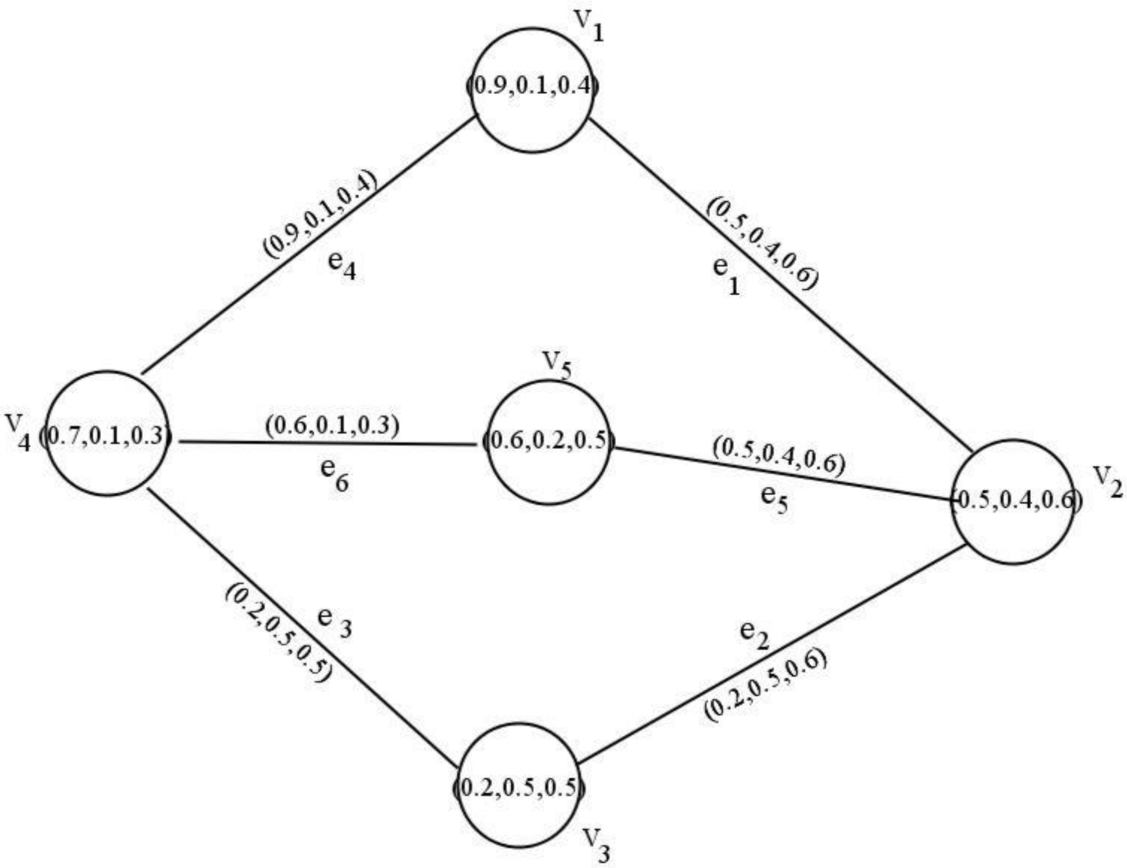

Figure 2: Total edge domination in a Single Valued Neutrosophic Graph

Here $\{e_1, e_2, e_3, e_4, e_6\}$,$\{e_1, e_2, e_4, e_5\}$, $\{e_1, e_2, e_3\}$, $\{e_1, e_4\}$, $\{e_1, e_3\}$, $\{e_2, e_3\}$ are total dominating sets and $\gamma'_{nted}(G) = 1.15$.

Definition 4.4

Let $G = (A, B)$ of $G^* = (V, E)$ be a single valued neutrosophic graph.

A secure edge dominating set S of V is called a total secure edge dominating set, if the subgraph $< S >$ induced by S is strongly connected. The total secure edge domination number of G is minimum cardinality taken over all total secure edge dominating sets of G and is denoted by $\gamma'_{ntsed}(G)$.

From Figure 2, $\{e_1, e_2, e_3, e_4, e_6\}$,$\{e_1, e_2, e_4, e_5\}$, $\{e_1, e_2, e_3\}$ are secure total dominating sets of G and $\gamma_{sntd}(G) = 1.8$.

Definition 4.5

If F is a minimum neutrosophic edge domination set which has the smallest cardinality then $F' \subseteq E - F$ is said to be neutrosophic inverse edge dominating set of G with respect to F if F' is a neutrosophic edge dominating set. The neutrosophic inverse edge domination number of G is minimum cardinality taken over all neutrosophic inverse edge dominating sets of G and is denoted by $\gamma^{-1}{}_{ned}(G)$.

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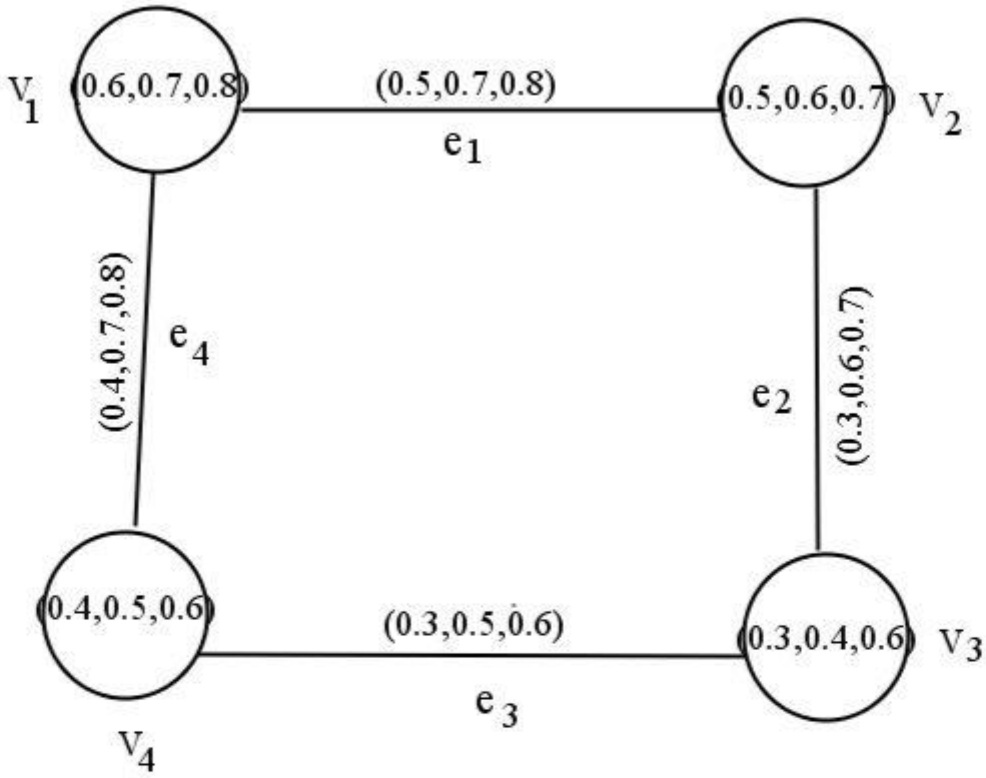

Figure 3: Neutrosophic inverse edge domination in a Single Valued Neutrosophic Graph

Here $\{e_1, e_4\}$, $\{e_1, e_3\}$, $\{e_1, e_2\}$ $\{e_2, e_3\}$, $\{e_2, e_4\}$, $\{e_3, e_4\}$ are minimal neutrosophic edge dominating sets of G and $F = \{ e_2, e_3\}$ and $F' = \{e_1 , e_4\}$ are neutrosophic edge dominating set and $\gamma^{-1}{}_{ned}(G) = 1.35$.

Definition 4.6

Let $G = (A, B)$ of $G^* = (V, E)$ be a single valued neutrosophic graph. “If F is a minimum neutrosophic secure edge domination set which has the smallest cardinality then $F' \subseteq E - F$ is said to be neutrosophic inverse secure edge dominating set of G with respect to F if F' is a neutrosophic secure edge dominating set. The neutrosophic inverse secure edge domination number of G is minimum cardinality taken over all neutrosophic inverse secure edge dominating sets of G and is denoted by $\gamma^{-1}{}_{nsed}(G)$.

From Figure 1, $F = \{e_1 , e_3 , e_6 \}$ is a minimum neutrosophic secure edge domination set and $F' = \{e_2, e_4 , e_5, e_7\}$ is a neutrosophic secure edge dominating set and $\gamma^{-1}{}_{nsed}(G) = 3.25$.

Definition 4.7

Let $G = (A, B)$ of $G^* = (V, E)$ be a single valued neutrosophic graph. If F is a minimum neutrosophic secure total edge domination set which has the smallest cardinality then $F' \subseteq E - F$ is said to be neutrosophic inverse secure total edge dominating set of G with respect to F if F' is a neutrosophic secure total edge dominating set. The neutrosophic inverse secure total edge domination number of G is minimum cardinality taken over all neutrosophic inverse secure total edge dominating sets of G and is denoted by $\gamma^{-1}{}_{nsted}(G)$.

DOI: https://doi.org/10.54216/JNFS.030201
Received: March 12, 2022 Accepted: June 22, 2022

From Figure 2, $F = \{ e_1 , e_2, e_3\}$ and $F' = \{e_4 , e_5, e_6\}$ are neutrosophic secure total edge dominating set and $\gamma^{-1}{}_{nsted}(G) = 2.15$.

Theorem 4.8 Let $G = (A, B)$ be a complete single valued neutrosophic graph. Then

(i) F is a neutrosophic edge dominating set iff F is neutrosophic secure edge dominating set.

(ii) F is neutrosophic total edge dominating set iff F is neutrosophic secure total edge dominating set.

(iii) F' is neutrosophic inverse edge dominating set iff F' is neutrosophic secure inverse edge domination set.

Proof:

Given $G = (A, B)$ is a complete single valued neutrosophic graph. By the definition of complete neutrosophic graph, we have $T_{\mathrm{B}}(u, v) = T_A(u) \wedge T_A(v)$, $I_{\mathrm{B}}(u, v) = I_A(u) \vee I_A(v)$ and $F_{\mathrm{B}}(u, v) = F_A(u) \vee F_A(v)$ for every $u, v \in V$.

Here all the arcs in $G = (A, B)$ are strong arcs.

(i) Let F be any neutrosophic edge dominating set in $G = (A, B)$. Now any edge $e \epsilon E - F$is adjacent to all the edges of F and $(F - \{f\}) \cup \{e\}$ is a neutrosophic edge dominating set for all $f \epsilon F$. Thus F is a neutrosophic secure edge dominating set of G. Conversely, by definition, every neutrosophic secure edge dominating set is a neutrosophic edge dominating set.

(ii) Let F be any neutrosophic total edge dominating set in $G = (A, B)$. By definition, the subgraph $< \mathrm{F} >$ induced by F is strongly connected. Now the replacement of any edge $e \epsilon F$ by some edge $f \epsilon E - F$ remains strongly connected as all the edges are strong. Thus F is a neutrosophic secure total edge dominating set of G. Conversely, by definition, every neutrosophic secure total edge dominating set is a neutrosophic total edge dominating set.

(iii) Let F' is neutrosophic inverse edge dominating set in $G = (A, B)$. By definition, F is a minimum neutrosophic edge domination set then there exists $F' \subseteq E - F$ is a neutrosophic edge dominating set. By (i), F' is a neutrosophic secure edge dominating set of G. Thus, F' is neutrosophic secure inverse edge dominating set of G. Conversely, by definition, every neutrosophic secure inverse edge domination set is a neutrosophic inverse edge dominating set.

Theorem 4.9

Every neutrosophic edge dominating set in F of a strong single valued neutrosophic graph $G = (A, B)$ contains a neutrosophic inverse edge domination set.

Proof:

Let F be a minimal neutrosophic edge dominating set of a single valued neutrosophic graph $G = (A, B)$. Since $G = (A, B)$ is strong, all the edges are strong edges. Then by theorem 4.8, if F is a minimal neutrosophic edge dominating set of SVNG G then $E - F$ is also a neutrosophic edge dominating set of SVNG G. Thus, $E - F$ is also a neutrosophic edge dominating set.

Hence every strong SVNG $G = (A, B)$ contains an inverse edge domination set.

DOI: https://doi.org/10.54216/JNFS.030201
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Theorem 4.10

The complement of any neutrosophic edge dominating set in single valued neutrosophic graph G is a neutrosophic edge dominating set of G.

Proof:

Let G = (A, B) be a single valued neutrosophic graph.

By the definition of edge domination, an edge subset F of E is called neutrosophic edge dominating set in G, if for every $e \epsilon E - F$, there exists at least one edge $f \epsilon F$ such that f dominates e. If $\bar{F}$ be the complement of neutrosophic edge dominating set of F then $f \epsilon \bar{F}$ and $e \epsilon E - \bar{F}$ such that f dominates e. i.e., for every $f \epsilon \bar{F}$ and $e \epsilon E - \bar{F}$ such that f dominates e in $\bar{G}$. Hence $\bar{F}$ is a neutrosophic edge dominating set of G.

Theorem 4.11

The complement of any neutrosophic secure edge dominating set in single valued neutrosophic graph G is a neutrosophic secure edge dominating set of G.

Proof:

Let G = (A, B) be a single valued neutrosophic graph.

If $\bar{F}$ is the complement of neutrosophic secure edge dominating set of F then $\bar{F}$ is also a dominating set of G. Now the replacement of any edge $e \epsilon \bar{F}$ by some edge $f \epsilon F$ remains strongly connected. Thus, the complement of any neutrosophic secure edge dominating set in single valued neutrosophic graph G is a neutrosophic secure edge dominating set of G.

Theorem 4.12

For any single valued neutrosophic graph G,

$$\gamma'_{ned}(G) \leq \gamma'_{nsed}(G) \leq \gamma^{-1}{}_{nsed}(G).$$

Proof:

Every neutrosophic secure edge dominating set is a neutrosophic edge dominating set. But minimum neutrosophic secure edge dominating set need not to be minimum neutrosophic edge dominating set and the cardinality of minimum neutrosophic secure edge dominating set will always exceeds or equals the cardinality of minimum neutrosophic edge dominating set.

I.e., $\gamma'_{nsed}(G) \geq \gamma'_{ned}(G)$.

Every neutrosophic inverse secure edge dominating set is obtained by a minimal neutrosophic secure edge dominating set of G. Therefore, the minimum cardinality of neutrosophic inverse secure edge dominating set will always exceeds or equals the minimum cardinality of neutrosophic secure edge dominating set. I.e., $\gamma^{-1}{}_{nsed}(G) \geq \gamma'_{nsed}(G)$.

Every neutrosophic inverse secure edge dominating set is a neutrosophic secure edge dominating set and every neutrosophic secure edge dominating set is a neutrosophic edge dominating set.

Hence every minimum neutrosophic inverse secure edge dominating set is a neutrosophic edge dominating set. Therefore, the minimum cardinality of neutrosophic inverse secure edge dominating set will always exceeds or equals the minimum cardinality of neutrosophic edge dominating set. I.e., $\gamma^{-1}{}_{nsed}(G) \geq \gamma'_{ned}(G)$.

Hence $\gamma'_{ned}(G) \leq \gamma'_{nsed}(G) \leq \gamma^{-1}{}_{nsed}(G)$.

DOI: https://doi.org/10.54216/JNFS.030201
Received: March 12, 2022 Accepted: June 22, 2022

Theorem 4.13

For any single valued neutrosophic graph G, $\gamma'_{nsed}(G) + \gamma^{-1}{}_{nsed}(G) \leq S(G)$.

Proof:

Let F be a minimum neutrosophic secure edge dominating set of neutrosophic graph G and $\gamma'_{nsed}(G) = k$. Of neutrosophic inverse secure edge dominating set there exists $F' \subseteq E - F$ is also a neutrosophic secure edge dominating set and $\gamma^{-1}{}_{nsed}(G) \leq l$. Here $S(G)$ is an edge cardinality of the single valued neutrosophic graph G. As F' cannot exceed the edge cardinality of $E - F$, we get $k + l \leq S(G)$. Hence $\gamma'_{nsed}(G) + \gamma^{-1}{}_{nsed}(G) \leq S(G)$.

5. Conclusion

The neutrosophic graph theory can model complex real-time problems with greater flexibility and precision than the fuzzy graph and intuitionistic fuzzy graphs. Numerous fields of science and technology, such as genetic algorithms, optimization methods, cluster analysis, and decision trees, now make extensive use of neurosophic graph theory. A neutrosophic graph was created by Florentin Smarandache using neutrosophic sets. Neutosophic models are more accurate, flexible, and system-compatible when compared to other conventional and fuzzy models. We introduced the concept of neutrosophic secure edge domination of neutrosophic graphs in this paper, and we plan to expand our work on the application to identify the most critical route in a network connectivity in a neutrosophic environment using neutrosophic secure edge domination.

Compliance with Ethical Standards

Conflict of Interest

The authors declare that they do not have any financial or associative interest indicating a conflict of interest in about submitted work.

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Received: March 12, 2022 Accepted: June 22, 2022

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DOI: https://doi.org/10.54216/JNFS.030201
Received: March 12, 2022 Accepted: June 22, 2022