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PERFECT G-ECCENTRIC DOMINATION IN FUZZY GRAPHS

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Abstract: A dominating set $D \subseteq V$ of a fuzzy graph $G(\sigma, \mu)$ is said to be a g-eccentric dominating set if for every vertex $v \in V - D$, there exists at least one g-eccentric vertex u of v in D. Adominating set $D \subseteq V(G)$ of a fuzzy graph $G(\sigma, \mu)$ is said to be a perfect g-eccentric dominating set, if for each vertex $v \in V - D$, there exists exactly one g-eccentric vertex u of v in D. The minimum cardinality among all the perfect g-eccentric dominating set is called perfect g-eccentric domination number. In this article, perfect g-eccentric dominating set and its number are introduced. Perfect g-eccentric domination number for some standard fuzzy graphs are obtained. Theorem related to perfect g-eccentric dominating set and its number for fuzzy graphs are stated and proved. Bounds on perfect g-eccentric domination number for some standard fuzzy graphs are obtained.

Keywords: Fuzzy graph, g-Eccentric dominating set, Perfect g-eccentric dominating set, Perfect g-eccentric domination number.

AMS Subject Classification 2020: 05C05, 05C12, 05C72.

1. Introduction

L. A. Zadeh[12] introduced the concept of fuzzy sets in 1965. Rosenfeld [8] developed the concept of Fuzzy Graphs(FG) in 1975. E. J. Cockayne and S. T. Hedetniemi[2] introduced the theory of domination in graph in 1977. Paul M. Weichsel [11] introduced the perfect domination in graphs in 1994. A. Somasundaram and S. Somasundaram [9] were introduced the concept of domination in FG independently in 1998. Bhuttani and A. Rosenfeld [1] introduced the concept of geodesies distance in FG in 2003. Janakiraman at et. [5], initiated the eccentric domination in graph in 2010. Linda.J.P and Sunitha M.S [6] introduced on the g-eccentric nodes and related concepts in FG in 2012. A. Mohamed Ismayil and S. Muthupandiyan[4] introduced the complementary nil g-eccentric domination in fuzzy graphs in the year 2020.

In this article, the perfect g-eccentric point set, perfect g-eccentric dominating set and their number in FG are introduced. Also obtained the bounds on the perfect g-eccentric domination number for some standard FG as well as some theorems related to perfect g-eccentric domination in FG are stated and proved.

The terms graph and fuzzy graph theoretic terminologies can refer Harary[3] and Rosenfeld and L.A. Zadeh[8, 12] respectively. In this paper, G is a connected fuzzy graph unless otherwise stated.

2. Basic Definitions

In this section the following definitions willhelp the readers comprehend the core concepts.

Definition 2.1.[4, 10] A FG $G=(\sigma,\mu)$ is characterized with two functions σ on V and μ on $E\subseteq V\times V$, where $\sigma: V\to[0,1]$ and $\mu: E\to[0,1]$ such that $\mu(x,y)\leq\sigma(x)\wedge\sigma(y), \forall x,y\in V$. We indicate the crisp grpah $G^*=(\sigma^*,\mu^*)$ of the fuzzy graph $G=(\sigma,\mu)$ where $\sigma^*=\{x\in V:\sigma(x)>0\}$and $\mu^*=\{(x,y)\in E:\mu(x,y)>0\}$. The order and size of a FG G are defined by $p=\sum_{u\in V}\sigma(u)$ and $q=\sum_{uv\in E}\mu(u,v)$ respectively.

Definition 2.2. [1,4, 10]Let G be a FG. A path P of length n is a sequence of distinct nodes $u_0,u_1,\ldots,u_n$ such that $\mu(u_{i-1},u_i)>0, i=1,2,.\,.,n$ and strength of the path $P$is $(P)=\min\{\mu(u_{i-1},u_i), i=1,2,,\ldots n\}$. The strength of connectedness between nodes u and v is defined as the maximum strengths of all paths between u and v and is denoted by $CONN_G(u,v)$. An$u-v$ path P is called a Strong path if it contains only strong arcs. An $u-v$ path is called strongest $u-v$ path if its strength is equals $CONN_G(u,v)$. An arc is strong iff its weight is equal to the strength of connectedness of its end nodes. i.e., $\mu(u,v)\geq CONN_{G-(u,v)}(u,v)$. If an arc (u,v) is strong, then u dominates v or $v$dominates u.

Definition 2.3.[1, 4]A strong path P from u to v is called geodesics if there is no shorter strong path from u to v and a length of a $u-v$ geodesic is the geodesic distance(gdistance) from u to v denoted by $d_g(u,v)$. The geodesic eccentricity(g-eccentricity) $e_g(u)$ of a node u in a connected FG G is given by $e_g(u)=$

$\max\{d_g(u, v, v \in V\}$.The g-eccentric set of a vertex u is defined and denoted by $E_g(u) = \{v: v \in d_g(u, v) = e_g(u)\}$. The minimum g-eccentricity among the vertices of G is called g-radius and denoted by $r_g(G) = \min\{e_g(u), u \in V\}$. The maximum g-eccentricity among the vertices of G is called g-diameter and denoted by $d_g(G) = \max\{e_g(u), u \in V\}$. A vertex v is said to be a g-central node if $e_g(v) = r_g(G)$. Also, a vertex v in G is said to be a g-peripheral node if $e_g(v) = d_g(G)$. A FG G is said to be self centered if $r_g(G) = d_g(G)$.

Definition 2.4.[7, 11]A subset D of V is called a dominating set of a FG G if for every $v \in V - D$ there exists $u \in D$ such that $u$dominates v.A dominating set D of V of a FG G is called a perfect dominating set if for every $v \in V - D$, there exists exactly one vertex $u \in D$ such that u dominates v.

Definition 2.5.[4]A subset $S \subseteq V$ in a FG G is said to be a g-eccentric point set(gEP-set) if for every $v \in V - S$, there exists at least one g-eccentric point u of v in S.

Definition 2.6.[4] A dominating set D of V of a FG G is called a g-eccentric dominating set(gED-set) of G if for every $v \in V - D$ there exists at least a g-eccentric vertex $u \in D$ of v.

3. Perfect g-Eccentric Point set in Fuzzy Graphs

In this section, the perfect g-eccentric point set, perfect g-eccentric point number and some observations are given in a FG with applicable examples.

Definition 3.1. A set $S \subseteq V$ in a FGG on $G^*(V, E)$ is said to be a perfect g-eccentric point set(PgEP-set) if for every $x \in V - S$, there exists exactly one g-eccentric point y of x in S. The perfect g-eccentric point set S of G is a minimal perfect g-eccentric point set if there is no proper subset S' of S is a perfect g-eccentric point set of G. The minimum cardinality of a minimal perfect g eccentric point set of G is called the perfect g-eccentric number and is denoted by $e_{pg}(G)$ and simply denoted by e_{pg}. The maximum cardinality of a minimal perfect g-eccentric point set is called upper perfect g-eccentric number and is denoted by $E_{pg}(G)$ and simply denoted by E_{pg}.

Note 3.1. The minimum PgEP-set is denoted by $e_{pg} -$ set.

Example 3.1.

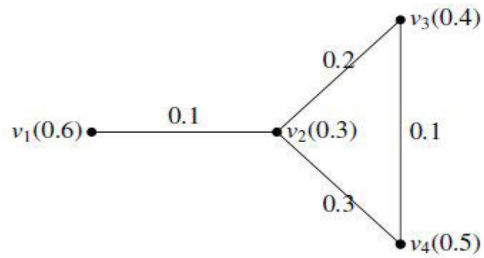

Figure 1: Fuzzy Graph $G(\sigma, \mu)$

In the FG G given in figure 1, the g-eccentricity of v_1, v_2, v_3 and v_4 are $e_g(v_1) = 2, e_g(v_2) = 1$ and $e_g(v_3) = 2, e_g(v_4) = 2$ respectively and the g-eccentric point set of v_1, v_2, v_3 and v_4 are $E_g(v_1) = \{v_3, v_4\}, E_g(v_2) = \{v_1, v_3, v_4\}, E_g(v_3) = \{v_1, v_4\}$ and $E_g(v_4) = \{v_1, v_3\}$ respectively.The e_{pg}.- sets are $S_1 = \{v_3\}$ and $S_2 = \{v_1\}$. Hence, $e_{pg}(G) = 0.4$and $E_{pg}(G) = 0.6$.

Observation 3.1.

1 If S is a PgEP-set, then $S' \supset S$ is also a PgEP-set.

2 If S is a minimal PgEP- set, then $S' \subset S$ is not a PgEP-set.

3 In a fuzzy tree, every PgEP-set contains at least one pendent vertex.

4 For any FG $G, e_{pg}(G) \leq E_{pg}(G)$.

5 For any FG$G, e_g(G) \leq e_{pg}(G)$.

6 The complement of a e_{pg}- set need not be a PgEP-set.

Example 3.2.

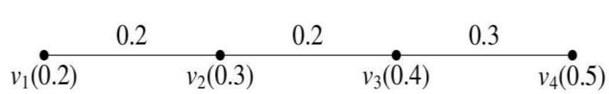

Figure 2: Path Fuzzy Graph$P_\sigma, |\sigma^*| = 4$

The path FG given in figure 2 , the e_{pg}.-set is $S=\{v_1,v_4\}$. The complement of $SV-S=\{v_2,v_3\}$is not a PgEP-set.

Preposition 3.1. Let K_σ be any complete FG. Then $e_{pg}(K_\sigma)=\sigma_0, |\sigma^*|=n$, where $\sigma_0=\min\{\sigma(u), u\in V\}$.

Proof. Let K_σ be any complete FG. Then $\mu(u,v)=\sigma(u)\wedge\sigma(v), \forall u,v\in V$. Therefore, each vertex has exactly $(n-1)$ g-eccentric points. Hence, every singleton set is a minimum pgep-set. Therefore, $e_{pg}(K_\sigma)=\min\{\sigma(u), u\in V\}.=\sigma_0$.

Preposition 3.2. Let K_{σ_1,σ_2} be a complete bipartite FG, where $|\sigma_1^*|=m$ and $|\sigma_2^*|=$ n. Then $e_{pg}\left(K_{\sigma_1,\sigma_2}\right)=\sigma_{10}+\sigma_{20}$, where $\sigma_{10}=\min_{u\in V_1}\sigma(u)$ and $\sigma_{20}=\min_{v\in V_2}\sigma(v)$.

Proof. Let K_{σ_1,σ_2} be a complete bipartite FG, where $|\sigma_1^*|=m$and $|\sigma_2^*|=n$. For σ_1, the g-eccentric set of each vertices are $E_g(u_1)=\{u_2,u_3,\cdots,u_m\}, E_g(u_2)=\{u_1,u_3,\cdots,u_m\},\cdots,E_g(u_n)=\{u_2,u_3,\cdots,u_(m-1)\}$ and similarly, for the vertex set σ_2 the g-eccentric set of each vertices are $E_g(v_1)=\{v_2,v_3,\cdots,v_n\}, E_g(v_2)=\{v_2,v_3,\cdots,v_n\},\cdots,E_g(v_n)=\{v_2,v_3,\cdots,v_{(n-1)}\}$. Therefore, the e_{pg}-set is $=(u,v)$, let $\sigma_{10}=\min\{\sigma(u), u\in V_1\}$ and $\sigma_{20}=\min\{\sigma(v), v\in V_2\}$. Hence, $e_{pg}\left(K_{\sigma_1,\sigma_2}\right)=\sigma_{10}+\sigma_{20}$

Preposition 3.3. Let S_σ be a star FG. Then $e_{pg}(S_\sigma)\leq 1, |\sigma^*|=n, n\geq 3$.

Proof. Let S_σ be any star FG. Let $c\in V$ be g-central vertex of a star FG. Then, all vertices in $V-\{c\}$ are the g-peripheral vertices. Now, all the g-peripheral vertices is the g-eccentric point of g-central vertex and a vertex in $V-\{c\}$ has a g-eccentric points as all other g-peripheral vertices except g-central vertex c. Therefore, the PgEP-set is $=\min\{\sigma(u), u\in V-(c)\}$. Hence, $e_{pg}S_\sigma\leq 1$.

Preposition 3.4. Let P_σ be any path FG. Then$e_{pg}(P_\sigma)=\sigma_0, |\sigma^*|=2,3$.

Proof. Let $P_\sigma, |\sigma^*|=n$ be any path FG.

Case(i) If $n=2$

One of the vertex in a path FG is a perfect g-eccentric point of other and Therefore,

$$\begin{aligned} e_{pg}(P_\sigma) &= \min_{u\in V}\sigma(u) \\ &= \sigma_0 \end{aligned}$$

Case(ii)If $n = 3$

Every g-peripheral vertex is a g-eccentric point of other g-peripheral vertex and a g-central vertex has a g-eccentric point of every g-peripheral vertex. Therefore, every singleton minimum g-peripheral vertex is a perfect g-eccentric point set of P_σ. Therefore, $e_{pg}(P_\sigma) = \sigma_0$.

Preposition 3.5. Let P_σ be any path FG.

$$e_{pg}(P_\sigma) \leq \begin{cases} 2, & \text{if } |\sigma^*| = n, n \geq 4, n \text{ is even} \\ 3, & \text{if } |\sigma^*| = n, n \geq 5, n \text{ is odd} \end{cases}$$

Proof. Let $P_\sigma, |\sigma^*| = n$ be any path fuzzy graph

Case(i) If n is even, $n \geq 4$:

Let the g-eccentric set of vertices are $E_g(u_1) = E_g(u_2) = \cdots = E_g\left(u_{\frac{n}{2}}\right) = \{u_n\}$and $E_g\left(u_{\frac{n}{2}+1}\right) = E_g\left(u_{\frac{n}{2}+2}\right) = \cdots = E_g(u_n) = \{u_1\}$. Then the PgEP-set is $= \{u_1, u_n\}$. Since, every vertex of $V - S$ has exactly one g-eccentric point in S. Hence, $e_{pg}(P_\sigma) \leq 2$

Case(ii):If n is odd, $n \geq 5$:

Now, $E_g(u_1) = E_g(u_2) = \cdots = E_g\left(u_{\frac{n+1}{2}} - 1\right) = \{u_n\}, E_g\left(u_{\frac{n+1}{2}}\right) = \{u_1, u_n\}$and $E_g\left(u_{\frac{n+1}{2}} + 1\right) = \cdots = E_g(u_n) = \{u_1\}$. Then, the PgEP-set is $S = \left\{u_1, u_{\frac{n+1}{2}}, u_n\right\}$. Since, every vertex of $V - S$ has exactly one g-eccentric point in S. Hence, $e_{pg}(P_\sigma) \leq 3$

4 Perfect g-Eccentric Domination in Fuzzy Graphs

In this section, the perfect g-eccentric dominating set and its numbers are defined in a FG. The relations between domination numbers, g-eccentric number, g-eccentric domination number and perfect g-eccentric domination number are obtained. The perfect g-eccentric domination numbers of some well known FG are foundFG and theorems related to perfect g-eccentric domination numbers are given and demonstrated.

Definition 4.1. A dominating set $D \subseteq V(G)$ is said to be a perfect g-eccentric dominating set(PgED-set) in a FG G if for every $v \in V - D$, there exists exactly one g-eccentric point $u \in D$ of v. A perfect g-eccentric dominating set is a minimal perfect g-eccentric dominating set if no proper sub set $D' \subset D$ is a perfect g eccentric dominating set. The minimum cardinality taken over all minimal perfect g-eccentric dominating set is called perfect g-eccentric domination number and is denoted by $\gamma_{pged}(G)$. The maximum cardinality taken over all minimal perfect g-eccentric dominating set is called upper perfect g-eccentric domination number and is denoted by $\Gamma_{pged}(G)$.

Note 4.1. The minimumPgED-set of a FG is denoted by γ_{pged}-set .

Example 4.1.

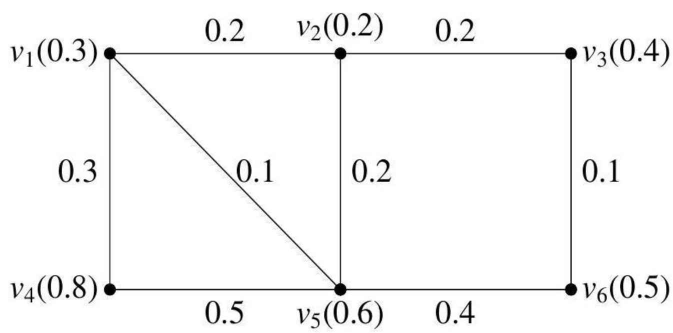

Figure 3: Fuzzy Graph $G(\sigma, \mu)$

The FG given in figure 3, we observe that,

1 The set $D_1 = \{v_2, v_5\}$ is γ-set and $\gamma(G) = 0.8$.

2 The set $D_2 = \{v_1, v_3, v_6\}$ is γ_{ged} -set and $\gamma_{ged}(G) = 1.2$.

3 The set$D_3 = \{v_1, v_3, v_5, v_6\}$ and $D_4 = \{v_2, v_3, v_4, v_6\}$ are minimal PgED-sets. Hence, $\gamma_{pged}(G) = 1.8$and $\Gamma_{pged}(G) = 1.9$.

Observation 4.1.

1 If D is a PgED-set, then $D' \supset D$ is also PgED-set.

2 If D is a minimal PgED-set, then $D' \subset D$ is not a PgED-set.

3 For any FG $G, \gamma(G) \leq \gamma_{ged}(G) \leq \gamma_{pged}(G) \leq \Gamma_{pged}(G)$.

4 If a connected FG G has more than one pendent vertex then the PgED-set contains at least two pendent vertex.

5 Every PgED-set is a gED-set but the converse need not be true.

6 The complement of a γ_{pged}-set need not be PgED-set.

Example 4.2.

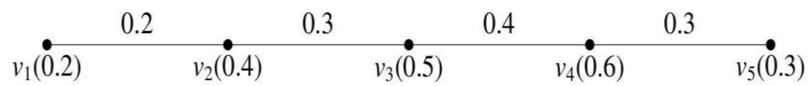

Figure 4: Path Fuzzy Graph$P_\sigma, |\sigma^*| = 5$

Let us consider the figure 4 given in example 4.2, We observe that

1 The set $D = \{v_1, v_3, v_5\}$ is gED-set and PgED-set. Also, the set $D_1 = \{v_1, v_2, v_5\}$ is a gED-set but not a PgED-set.

2 Let the set $D = \{v_1, v_3, v_5\}$ is a PgED-set but the complement of D is $V - D = \{v_2, v_4\}$ not a PgED-set.

Observation 4.2. Let D be dominating set in a FGG and S be a e_{pg}-set of G. Then clearly $D \cup S$ is γ_{pged}-set of G.

Observation 4.3. For any connected FGG.

(i) $\gamma(G) \leq \gamma_{ged}(G) \leq \gamma_{pged}(G)$

(ii) $\gamma_{pged}(G) \leq \Gamma_{pged}(G)$.

(iii) If $\text{diam}_g(G) = \text{rad}_g(G)$, then $\gamma_{pged}(G) = \gamma(G)$.

Theorem 4.1. For any connected $FGG, \gamma_{pged}(G) \leq \gamma(G) + e_{pg}(G)$.

Proof. By the observation 4.2, every γ_{pged}-set is a union of dominating set and perfect g-eccentric point set. Hence, $\gamma_{pged}(G) \leq \gamma(G) + e_{pg}(G)$.

Result 4.1. If $G(\sigma, \mu)$ is a disconnected FG, then $\gamma_{pged}(G) = \gamma(G)$. Since, vertices from different components are g-eccentric to each other.

Note 4.2. $\gamma_{pged}(G) = p$ if and only if $G(\sigma,\mu) = \bar{K}_\sigma$.

Theorem 4.2. For any complete $FG K_\sigma, \gamma_{\text{pged}}(K_\sigma) = \sigma_0$, where $\sigma_0 = \min_{u\in V}\sigma(u)$.

Proof. If $G = K_\sigma$ be a complete FG, then $\text{rad}_g(G) = \text{diam}_g(G) = \sigma_0$. Hence any vertex $u \in V(G)$ dominates all other vertices and also perfect g-eccentric point of other vertices. Hence, $\gamma_{pged}(K_n) = \sigma_0$.

Observation 4.4. For any $FG G, \sigma_0 \le \gamma_{pged}(G) \le p$, where $\sigma_0 = \min_{u\in V}\sigma(u)$ and p is the order of $FG\ G$.

Theorem 4.3. For a complete bipartite FG, $\gamma_{\text{pged}}\left(K_{\sigma_1,\sigma_2}\right) = \sigma_{10} + \sigma_{20}$, where $\sigma_{10} = \min_{u\in V_1}\sigma(u)$ and $\sigma_{20} = \min_{v\in V_2}\sigma(v)$.

Proof. If $\left(K_{\sigma_1,\sigma_2}\right), \sigma = \sigma_1 \cup \sigma_2$, be any complete bipartite FG, where $|\sigma_1^*| = m$ and $|\sigma_2^*| = n$ then each point u of V_1 is adjacent to every point v of V_2 and vice versa. By theorem 4.1 $D = \{u, v\}, u = \min_{u\in V_1}\sigma(u)$ and $v = \min_{v\in V_2}\sigma(v)$ is a PgEP-set and also D is a minimum dominating set of K_{σ_1,σ_2}. Hence, $\gamma_{pged}\left(K_{\sigma_1,\sigma_2}\right) = \sigma_{10} + \sigma_{20}$.

Corollary 4.3.1. For a star $FG, \gamma_{pged}\left(K_{\sigma_1,\sigma_2}\right) = \sigma_{10} + \sigma_{20}, |\sigma_1^*| = 1$ and $|\sigma_2^*| \ge 1$.

Theorem 4.4. Let D_1 and D_2 be two disjoint PgED-sets of a FGG. Then $|D_1| = |D_2|$

Proof. Let G be a FG. Let D_1 and D_2 be any two disjoint PgED-sets. For every vertex x in D_1 there is unique vertex $v(x)$ in D_2 which is adjacent to x and exactly a g-eccentric vertex to x. Also, for every vertex y in D_2 there is unique vertex $u(y)$ in D_1 which is adjacent to y and exactly a g-eccentric vertex to y. $\therefore |D_1| = |D_2|$.

Corollary 4.4.1. Let G be any FG and if D_1 and D_2 be any two PgED-sets such that $|D_1| = |D_2|$ then $D_1 \cap D_2 = \emptyset$.

Corollary 4.4.2. Let G be a FG with n vertices. If there is a PgED-set D with $|D| < n/2$ or $|D| \ge n/2$ then $V - D$ is not a PgED-set.

Theorem 4.5. Let D be a (minimal) γ_{pged}- set of connected FGG. Then $V - D$ is a gED-set of G

Proof. Let D be a minimal PgED- set of connected FG G. Suppose $V - D$ is not a gED-set. Then there exists a vertex $v \in D$ such that v (is not dominated by any vertex) has no g-eccentric vertex in $V - D$. Since G is connected, v is strong neighbor of atleast one vertex in $D - \{v\}$. Then $D - \{v\}$ is a gED-set, which is contradicts to the minimality of D. Thus every vertex in D is strong neighbor of atleast one vertex in $V - D$. Hence $V - D$ is a gED-set.

Result 4.2. Every γ_{pged}-set of a FG G is a minimal PgED-set but the converse need not be true.

Theorem 4.6 Let G be a FG and let D be a PgED-set. Then D is a minimal PgED-set if and only if for each vertex $u \in D$, satisfies one of the following condition:

1. $N_s(u) \cap D = \phi$or$E_g(u) \cap D = \phi$.

2. There exists some $v \in V - D$ such that (i) $N_s(v) \cap D = \{u\}$ or (ii) $E_g(v) \cap D = \{u\}$ or (iii) $E_g(v) \cap D \neq \phi$.

Proof: Suppose that D is a minimal PgED-set of a FGG. Then for every $u \in D$, $D - \{u\}$ is not a PgED- set. Then (i) there exists some vertex $v \in V - D \cup \{u\}$ which is not dominated by any vertex in $D - \{u\}$ or (ii) there exists $v \in V - D \cup \{u\}$ such that v has no g-eccentric point in $D - \{u\}$ or (iii) there exists $v \in V - D \cup \{u\}$ such that v has at least two g-eccentric point in $D - \{u\}$.

Case (1) If $= u$, then (i) u has no strong neighbor in $D - \{u\}$. Hence $N_s(u) \cap D = \phi$ or (ii) $u$has no g-eccentric point in $D - \{u\}$. Hence $E_g(u) \cap D = \phi$ or (iii) $u$has at least two g-eccentric point in $-\{u\}$. Hence □□(□) ∩ □ ≠ □

Case (2) □ ≠ □, then (i) If □ is not dominated by □ − {□} but is dominated by □, then □ is adjacent to only □ in □, that is □□(□) ∩ □ = {□}. (ii) Suppose □ has no g-eccentric point in □ − {□} but □ has a g-eccentric point in □ that is □□(□) ∩ □ = {□}. (iii) Suppose □ has at least two g-eccentric point in □ − {□} but □ has at least two g-eccentric point in □ that is □□(□) ∩ □ ≠ □.

Conversely, suppose that □ is a PgED-set and for each □ ∈ □ one of the conditions holds.

Assume that □ is not a minimal PgED-set, then there exists a vertex □ ∈ □ such that □ − {□} is a PgED-set. Therefore, □ is strong neighbor to at least one vertex □ in□ − {□} or □ has a g-eccentric point in □ − {□}. Hence, condition (1) does not hold.

Also, if □ − {□} is a PgED-set, then every element □ in □ − □ is strong neighbor to exactly one vertex in □ − {□} or □ has exactly one g-eccentric point in □ − {□}or □□(□) ∩ □ ≠ □.

Therefore, condition (2) does not hold. This is a contradiction to our assumption that for each ∈ , satisfies one of the condition. Hence, is a minimal PgED-set.

6. Conclusion

The perfect g-eccentric point set, perfect g-eccentric dominating set, its number and bounds for this numbers in fuzzy graphs are discussed in this paper.g-Eccentric perfect dominating set and perfect g-eccentric perfect dominating set in fuzzy graphs may be discuss in future.

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