TWMS J. App. and Eng. Math. V.14, N.3, 2024, pp. 957-965

SWITCHING OF VERTEX ON SOME GRAPHS WITH GEOMETRIC MEAN 3-EQUITABLE LABELING

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Abstract. For a graph H with a vertex set $P(H)$ and an edge set $Q(H)$, if map $g : P(H) \to \{0, 1, 2\}$ and its induced map $g^* : Q(H) \to \{0, 1, 2\}$ defined by $g^*(xy) = \lceil \sqrt{g(x)g(y)} \rceil$; $\forall xy \in Q(H)$, satisfies the absolute difference of the number of vertices (edges) with labeled x and labeled y is at most 1(where $\forall x, y \in \{0, 1, 2\}$) then g is called a geometric mean 3 - equitable labeling. In this paper, we investigate a geometric mean 3-equitable labeling of the graph obtained from switching of any vertex with degree one in path P_r for $r \equiv 1 \pmod 3$, switching of any vertex other than the support vertices in path P_r for $r \equiv 1, 2 \pmod 3$ and switching of any vertex in cycle C_r for $r \equiv 1, 2 \pmod 3$.

Keywords: Switching operation, jewel graph, mean graph, path, cycle.

AMS Subject Classification: 05C78.

1. Introduction and Preliminaries

In this article, we deal with finite, simple, undirected graph. Consider a graph H with a vertex set $P(H)$ and an edge set $Q(H)$, where $|P(H)|$ and $|Q(H)|$ are the cardinality of the vertex set and edge set of a graph. For other terminology, we use Harary [5] and of graph labeling as in Gallian [4]. Cahit [1] introduced cordial labeling in 1987. After that, Cahit [2] generalized the concept of cordial labeling as k-equitable labeling in 1990. Similarly, Ponraj et al. [7] presented the new concept mean cordial labeling in 2012. Inspired from mean cordial labeling and 3 - equitable labeling, Chitra Lakshmi and Nagarajan [3] presented geometric mean cordial labeling in 2017. After that, Kaneria et al.[6] renamed geometric mean cordial labeling as a geometric mean 3-equitable labeling and proved that some graphs are geometric mean 3-equitable. In 2021, Shrimali and Rathod [9] derived the

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§ Manuscript received: June 24, 2022; accepted: September 12, 2022.

graph obtained by switching of a vertex in path and cycle are vertex-edge neighborhood prime graphs. In 2022, Prajapati and Patel [8] proved that the graph obtained by switching of any vertex with degree one in path with k vertices for $k \geq 3$ and odd k, switching of vertex with degree two in path with k vertices except vertices u_2 or u_{k-1} with $k > 4$ and switching of any vertex in cycle are an edge product cordial graphs.

Definition 1.1. [3]. *Let $g : P(H) \to \{0, 1, 2\}$ be a vertex labeling function such that the absolute difference of the number of vertices with labeled p and labeled q is at most 1. If the induced edge labeling function $g^* : Q(H) \to \{0, 1, 2\}$ defined by $g^*(xy) = \lceil \sqrt{g(x)g(y)} \rceil$; $\forall xy \in Q(H)$ satisfies the condition that the absolute difference of the number of edges with labeled p and labeled q is at most 1, where $\forall p, q \in \{0, 1, 2\}$ then g is called a geometric mean 3 - equitable labeling.*

Definition 1.2. [8, 9]. *A graph obtained by fetching a vertex x of H, eliminating the adjacent edges of x and by adding new edges that are joining x to their non-adjacent vertices in H is called vertex switching H_x of H.*

2. Main Results

Theorem 2.1. *The graph obtained from switching of any vertex in cycle C_r is a geometric mean 3 - equitable for $r \equiv 1, 2$ (mod 3).*

Proof. Let $x_1, x_2, \ldots, x_{r-1}$ and x_r be the vertices of a cycle C_r. Suppose H_{x_1} is the graph obtained from switching of a vertex x_1 in C_r. In H_{x_1}, every vertex x_i other than x_2 and x_r join to x_1. We note that $|P(H_{x_1})| = r$ and $|Q(H_{x_1})| = 2r - 5$.

Case (i) $r \equiv 1$ (mod 3)

Define $g : P(H_{x_1}) \to \{0, 1, 2\}$ as :

$g(x_1) = 1$,

$$g(x_k) = \begin{cases} 0, & \text{if } 2 \leq k \leq \frac{r+2}{3}; \\ 1, & \text{if } \frac{r+5}{3} \leq k \leq \frac{2r+1}{3}; \\ 2, & \text{if } \frac{2r+4}{3} \leq k \leq r \end{cases}$$

It's induced edge map $g^* : Q(H_{x_1}) \to \{0, 1, 2\}$ is,

$$g^*(x_1 x_k) = \begin{cases} 0, & \text{if } 3 \leq k \leq \frac{r+2}{3}; \\ 1, & \text{if } \frac{r+5}{3} \leq k \leq \frac{2r+1}{3}; \\ 2, & \text{if } \frac{2r+4}{3} \leq k \leq r - 1 \end{cases}$$

and

$$g^*(x_k x_{k+1}) = \begin{cases} 0, & \text{if } 2 \leq k \leq \frac{r+2}{3}; \\ 1, & \text{if } \frac{r+5}{3} \leq k \leq \frac{2r-2}{3}; \\ 2, & \text{if } \frac{2r+1}{3} \leq k \leq r - 1. \end{cases}$$

Thus $v_g(0) = \frac{r-1}{3} = v_g(1) - 1 = v_g(2)$ and $e_g(0) = \frac{2r-5}{3} = e_g(1) = e_g(2)$.

Case (ii) $r \equiv 2$ (mod 3)

Define $g : P(H_{x_1}) \to \{0, 1, 2\}$ as :

$g(x_1) = 1$, $g(x_r) = 0$,

$$g(x_k) = \begin{cases} 0, & \text{if } 2 \leq k \leq \frac{r+1}{3}; \\ 1, & \text{if } \frac{r+4}{3} \leq k \leq \frac{2r-1}{3}; \\ 2, & \text{if } \frac{2r+2}{3} \leq k \leq r - 1 \end{cases}$$

It's induced edge map $g^* : Q(H_{x_1}) \to \{0, 1, 2\}$ is,
$g^*(x_{r-1}x_r) = 0$,

$$g^*(x_1x_k) = \begin{cases} 0, & \text{if } 3 \le k \le \frac{r+1}{3}; \\ 1, & \text{if } \frac{r+4}{3} \le k \le \frac{2r-1}{3}; \\ 2, & \text{if } \frac{2r+2}{3} \le k \le r-1 \end{cases}$$

and

$$g^*(x_kx_{k+1}) = \begin{cases} 0, & \text{if } 2 \le k \le \frac{r+1}{3}; \\ 1, & \text{if } \frac{r+4}{3} \le k \le \frac{2r-4}{3}; \\ 2, & \text{if } \frac{2r-1}{3} \le k \le r-2. \end{cases}$$

Thus $v_g(0) = \frac{r+1}{3} = v_g(1) = v_g(2) + 1$ and $e_g(0) = \frac{2r-4}{3} = e_g(1) + 1 = e_g(2)$.
So,both the cases, $|v_g(p) - v_g(q)| \le 1$ and $|e_g(p) - e_g(q)| \le 1$; $\forall p, q \in \{0, 1, 2\}$. Hence, H_{x_1} is a geometric mean 3 - equitable for $r \equiv 1, 2$ (mod 3). □

Example 2.1. *Geometric mean 3 - equitable labeling of H_{x_1} obtained from C_8 is in Figure 1.*

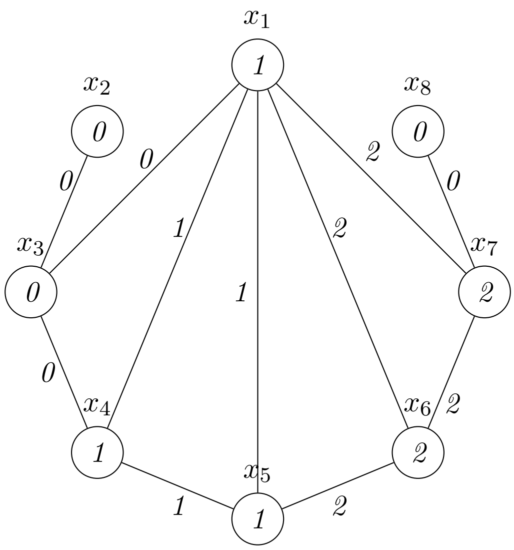

FIGURE 1. H_{x_1} obtained from C_8

Theorem 2.2. *The graph obtained from switching of any vertex of degree one in path P_r is a geometric mean 3 - equitable for $r \equiv 1$ (mod 3).*

Proof. Let x_1, x_2, $\ldots$, x_{r-1} and x_r be the vertices of a path P_r. Suppose H_{x_1} is the graph obtained from switching of a vertex of degree one that is x_1 in P_r. In H_{x_1}, every vertex x_i except x_2 join to x_1. We note that $|P(H_{x_1})| = r$ and $|Q(H_{x_1})| = 2r - 4$. Define $g : P(H_{x_1}) \to \{0, 1, 2\}$ as :
$g(x_1) = 1$,

$$g(x_k) = \begin{cases} 0, & \text{if } 2 \le k \le \frac{r+2}{3}; \\ 1, & \text{if } \frac{r+5}{3} \le k \le \frac{2r+1}{3}; \\ 2, & \text{if } \frac{2r+4}{3} \le k \le r \end{cases}$$

It's induced edge map $g^* : Q(H_{x_1}) \to \{0,1,2\}$ is,

$$g^*(x_1x_k) = \begin{cases} 0, & \text{if } 3 \le k \le \frac{r+2}{3}; \\ 1, & \text{if } \frac{r+5}{3} \le k \le \frac{2r+1}{3}; \\ 2, & \text{if } \frac{2r+4}{3} \le k \le r \end{cases}$$

and

$$g^*(x_kx_{k+1}) = \begin{cases} 0, & \text{if } 2 \le k \le \frac{r+2}{3}; \\ 1, & \text{if } \frac{r+5}{3} \le k \le \frac{2r-2}{3}; \\ 2, & \text{if } \frac{2r+1}{3} \le k \le r-1. \end{cases}$$

Thus $v_g(0) = \frac{r-1}{3} = v_g(1) - 1 = v_g(2)$ and $e_g(0) = \frac{2r-5}{3} = e_g(1) = e_g(2) - 1$. So, $|v_g(p) - v_g(q)| \le 1$ and $|e_g(p) - e_g(q)| \le 1$; $\forall p, q \in \{0,1,2\}$. Hence, H_{x_1} is a geometric mean 3 - equitable for $r \equiv 1$ (mod 3). □

Example 2.2. *Geometric mean 3 - equitable labeling of H_{x_1} obtained from P_{10} is in Figure 2.*

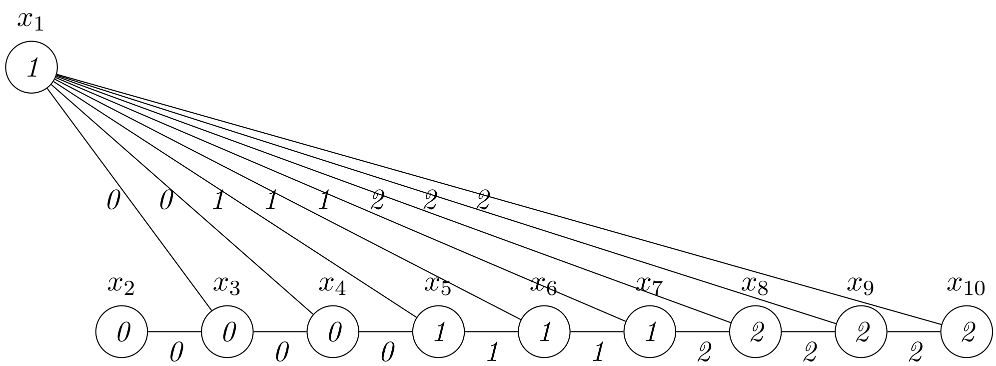

FIGURE 2. H_{x_1} obtained from P_{10}

Theorem 2.3. *The graph obtained from switching of any vertex other than the support vertices in path P_r is a geometric mean 3 - equitable for $r \equiv 1, 2$ (mod 3).*

Proof. Let $x_1, x_2, \ldots, x_{r-1}$ and x_r be the vertices of a path P_r. Suppose H_{x_i} $(3 \le i \le r-2)$ is the graph obtained from switching of a vertex of degree two that is x_i in P_r. In H_{x_i}, every vertex x_k except x_{i-1}, x_i or x_{i+1} join to x_i. We note that $|P(H_{x_i})| = r$ and $|Q(H_{x_i})| = 2r - 6$. In this proof we consider only x_i, $3 \le i \le \lceil \frac{r}{2} \rceil$ as rest of x_i proof is same.

Case (i) $r \equiv 1$ (mod 3)

Subcase (a) $3 \le i < \lceil \frac{r}{2} \rceil$

Define $g : P(H_{x_i}) \to \{0,1,2\}$ as :

$$g(x_k) = \begin{cases} 2, & \text{if } 1 \le k \le i-2; \\ 0, & \text{if } k = i-1; \\ 1, & \text{if } k = i; \\ 0, & \text{if } i+1 \le k \le \frac{r-4+3i}{3}; \\ 2, & \text{if } \frac{r-1+3i}{3} \le k \le \frac{2r+1}{3}; \\ 1, & \text{if } \frac{2r+4}{3} \le k \le r. \end{cases}$$

It's induced edge map $g^* : Q(H_{x_i}) \rightarrow \{0,1,2\}$ is,

$$g^*(x_i x_k) = \begin{cases} 2, & \text{if } 1 \leq k \leq i-2; \\ 0, & \text{if } i+2 \leq k \leq \frac{r-4+3i}{3}; \\ 2, & \text{if } \frac{r-1+3i}{3} \leq k \leq \frac{2r+1}{3}; \\ 1, & \text{if } \frac{2r+4}{3} \leq k \leq r \end{cases}$$

and

$$g^*(x_k x_{k+1}) = \begin{cases} 2, & \text{if } 1 \leq k \leq i-3; \\ 0, & \text{if } k = i-2; \\ 0, & \text{if } i+1 \leq k \leq \frac{r-4+3i}{3}; \\ 2, & \text{if } \frac{r-1+3i}{3} \leq k \leq \frac{2r+1}{3}; \\ 1, & \text{if } \frac{2r+4}{3} \leq k \leq r-1. \end{cases}$$

Subcase (b) $i = \lceil \frac{r}{2} \rceil$
Subcase (b - 1) r is odd
Define $g : P(H_{x_i}) \rightarrow \{0,1,2\}$ as :

$$g(x_k) = \begin{cases} 2, & \text{if } 1 \leq k \leq \frac{r-1}{3}; \\ 0, & \text{if } \frac{r+2}{3} \leq k \leq \frac{r-1}{2}; \\ 1, & \text{if } k = i = \frac{r+1}{2}; \\ 0, & \text{if } \frac{r+3}{2} \leq k \leq \frac{2r+1}{3}; \\ 1, & \text{if } \frac{2r+4}{3} \leq k \leq r. \end{cases}$$

It's induced edge map $g^* : Q(H_{x_i}) \rightarrow \{0,1,2\}$ is,

$$g^*(x_i x_k) = \begin{cases} 2, & \text{if } 1 \leq k \leq \frac{r-1}{3}; \\ 0, & \text{if } \frac{r+2}{3} \leq k \leq \frac{r-3}{2}; \\ 0, & \text{if } \frac{r+5}{2} \leq k \leq \frac{2r+1}{3}; \\ 1, & \text{if } \frac{2r+4}{3} \leq k \leq r \end{cases}$$

and

$$g^*(x_k x_{k+1}) = \begin{cases} 2, & \text{if } 1 \leq k \leq \frac{r-4}{3}; \\ 0, & \text{if } \frac{r-1}{3} \leq k \leq \frac{r-3}{2}; \\ 0, & \text{if } \frac{r+3}{2} \leq k \leq \frac{2r+1}{3}; \\ 1, & \text{if } \frac{2r+4}{3} \leq k \leq r-1. \end{cases}$$

Subcase (b - 2) r is even
Define $g : P(H_{x_i}) \rightarrow \{0,1,2\}$ as :

$$g(x_k) = \begin{cases} 2, & \text{if } 1 \leq k \leq \frac{r-1}{3}; \\ 0, & \text{if } \frac{r+2}{3} \leq k \leq \frac{r-2}{2}; \\ 1, & \text{if } k = i = \frac{r}{2}; \\ 0, & \text{if } \frac{r+2}{2} \leq k \leq \frac{2r+1}{3}; \\ 1, & \text{if } \frac{2r+4}{3} \leq k \leq r. \end{cases}$$

It's induced edge map $g^* : Q(H_{x_i}) \to \{0,1,2\}$ is,

$$g^*(x_i x_k) = \begin{cases} 2, & \text{if } 1 \le k \le \frac{r-1}{3}; \\ 0, & \text{if } \frac{r+2}{3} \le k \le \frac{r-4}{2}; \\ 0, & \text{if } \frac{r+4}{2} \le k \le \frac{2r+1}{3}; \\ 1, & \text{if } \frac{2r+4}{3} \le k \le r \end{cases}$$

and

$$g^*(x_k x_{k+1}) = \begin{cases} 2, & \text{if } 1 \le k \le \frac{r-4}{3}; \\ 0, & \text{if } \frac{r-1}{3} \le k \le \frac{r-4}{2}; \\ 0, & \text{if } \frac{r+2}{2} \le k \le \frac{2r+1}{3}; \\ 1, & \text{if } \frac{2r+4}{3} \le k \le r-1. \end{cases}$$

Thus in case - (i), $v_g(0) = \frac{r-1}{3} = v_g(1) - 1 = v_g(2)$ and $e_g(0) = \frac{2r-8}{3} = e_g(1) - 1 = e_g(2) - 1$.

Case (ii) $r \equiv 2 \pmod 3$

Subcase (a) $3 \le i < \lceil \frac{r}{2} \rceil$

Define $g : P(H_{x_i}) \to \{0,1,2\}$ as :

$$g(x_k) = \begin{cases} 2, & \text{if } 1 \le k \le i-2; \\ 0, & \text{if } k = i-1; \\ 1, & \text{if } k = i; \\ 0, & \text{if } i+1 \le k \le \frac{r-2+3i}{3}; \\ 2, & \text{if } \frac{r+1+3i}{3} \le k \le \frac{2r+2}{3}; \\ 1, & \text{if } \frac{2r+5}{3} \le k \le r. \end{cases}$$

It's induced edge map $g^* : Q(H_{x_i}) \to \{0,1,2\}$ is,

$$g^*(x_i x_k) = \begin{cases} 2, & \text{if } 1 \le k \le i-2; \\ 0, & \text{if } i+2 \le k \le \frac{r-2+3i}{3}; \\ 2, & \text{if } \frac{r+1+3i}{3} \le k \le \frac{2r+2}{3}; \\ 1, & \text{if } \frac{2r+5}{3} \le k \le r \end{cases}$$

and

$$g^*(x_k x_{k+1}) = \begin{cases} 2, & \text{if } 1 \le k \le i-3; \\ 0, & \text{if } k = i-2; \\ 0, & \text{if } i+1 \le k \le \frac{r-2+3i}{3}; \\ 2, & \text{if } \frac{r+1+3i}{3} \le k \le \frac{2r+2}{3}; \\ 1, & \text{if } \frac{2r+5}{3} \le k \le r-1. \end{cases}$$

Subcase (b) $i = \lceil \frac{r}{2} \rceil$

Subcase (b - 1) r is odd

Define $g : P(H_{x_i}) \to \{0,1,2\}$ as :

$$g(x_k) = \begin{cases} 2, & \text{if } 1 \le k \le \frac{r-2}{3}; \\ 0, & \text{if } \frac{r+1}{3} \le k \le \frac{r-1}{2}; \\ 1, & \text{if } k = i = \frac{r+1}{2}; \\ 0, & \text{if } \frac{r+3}{2} \le k \le \frac{2r+2}{3}; \\ 1, & \text{if } \frac{2r+5}{3} \le k \le r. \end{cases}$$

It's induced edge map $g^* : Q(H_{x_i}) \to \{0,1,2\}$ is,

$$g^*(x_ix_k) = \begin{cases} 2, & \text{if } 1 \leq k \leq \frac{r-2}{3}; \\ 0, & \text{if } \frac{r+1}{3} \leq k \leq \frac{r-3}{2}; \\ 0, & \text{if } \frac{r+5}{2} \leq k \leq \frac{2r+2}{3}; \\ 1, & \text{if } \frac{2r+5}{3} \leq k \leq r \end{cases}$$

and

$$g^*(x_kx_{k+1}) = \begin{cases} 2, & \text{if } 1 \leq k \leq \frac{r-5}{3}; \\ 0, & \text{if } \frac{r-2}{3} \leq k \leq \frac{r-3}{2}; \\ 0, & \text{if } \frac{r+3}{2} \leq k \leq \frac{2r+2}{3}; \\ 1, & \text{if } \frac{2r+5}{3} \leq k \leq r-1. \end{cases}$$

Subcase (b - 2) r is even
Define $g : P(H_{x_i}) \to \{0,1,2\}$ as :

$$g(x_k) = \begin{cases} 2, & \text{if } 1 \leq k \leq \frac{r-2}{3}; \\ 0, & \text{if } \frac{r+1}{3} \leq k \leq \frac{r-2}{2}; \\ 1, & \text{if } k = i = \frac{r}{2}; \\ 0, & \text{if } \frac{r+2}{2} \leq k \leq \frac{2r+2}{3}; \\ 1, & \text{if } \frac{2r+5}{3} \leq k \leq r. \end{cases}$$

It's induced edge map $g^* : Q(H_{x_i}) \to \{0,1,2\}$ is,

$$g^*(x_ix_k) = \begin{cases} 2, & \text{if } 1 \leq k \leq \frac{r-2}{3}; \\ 0, & \text{if } \frac{r+1}{3} \leq k \leq \frac{r-4}{2}; \\ 0, & \text{if } \frac{r+4}{2} \leq k \leq \frac{2r+2}{3}; \\ 1, & \text{if } \frac{2r+5}{3} \leq k \leq r \end{cases}$$

and

$$g^*(x_kx_{k+1}) = \begin{cases} 2, & \text{if } 1 \leq k \leq \frac{r-5}{3}; \\ 0, & \text{if } \frac{r-2}{3} \leq k \leq \frac{r-2}{2}; \\ 0, & \text{if } \frac{r+2}{2} \leq k \leq \frac{2r+2}{3}; \\ 1, & \text{if } \frac{2r+5}{3} \leq k \leq r-1. \end{cases}$$

Thus in case -(ii), $v_g(0) = \frac{r+1}{3} = v_g(1) = v_g(2) + 1$ and $e_g(0) - 1 = \frac{2r-7}{3} = e_g(1) = e_g(2)$. So, in both cases $|v_g(p) - v_g(q)| \leq 1$ and $|e_g(p) - e_g(q)| \leq 1$; $\forall p, q \in \{0,1,2\}$. Hence, H_{x_i} is a geometric mean 3 - equitable for $r \equiv 1, 2 \pmod 3$. □

Example 2.3. *Geometric mean 3 - equitable labeling of H_{x_3} obtained from P_8 is in Figure 3.*

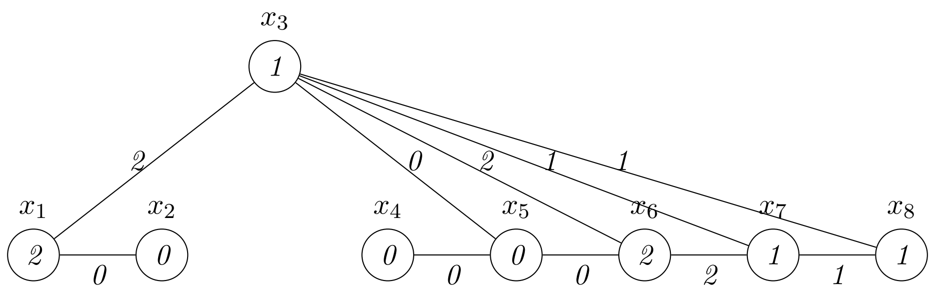

FIGURE 3. H_{x_3} obtained from P_8

Example 2.4. *Geometric mean 3 - equitable labeling of H_{x_7} obtained from P_{14} is in Figure 4.*

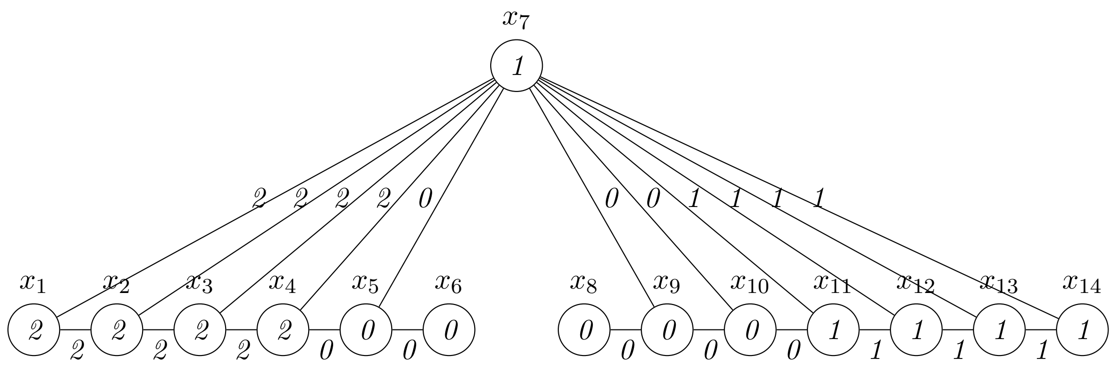

FIGURE 4. H_{x_7} obtained from P_{14}

3. Conclusions

We have derived three results on the graph obtained by switching of any vertex in cycle, switching of any vertex with degree one in path and switching of any vertex other than the support vertices in path are geometric mean 3-equitable graphs with some constraints.

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