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Many New Exact Solutions for Generalized Davey-Stewartson Equation with Arbitrary Power Nonlinearities Using Novel $(\frac{G'}{G})$-Expansion Method

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Abstract The novel $(\frac{G'}{G})$-expansion method is applied to solve generalized Davey-Stewartson equations with arbitrary power nonlinearities and obtain some exact traveling wave solutions. Via this method, we obtain kink wave solutions, anti-kink wave solutions, exact solitary wave solutions, periodic wave solutions. Also, it is shown that this method is influential for solving nonlinear partial differential equations (PDEs) in mathematical physics and engineering.

Keywords: Novel $(\frac{G'}{G})$-expansion method, Davey-Stewartson equation, exact traveling wave, solitary wave.

1 Introduction

In recent years, the study of the exact traveling wave solutions for nonlinear PDEs plays an important role in the area of solid state physics, optical fibers, plasma elastic media. Finding some exact traveling wave solutions has made great progression in mathematicians and physicists. Lots of methods have been presented, such as the inverse scattering method, Darboux transformation, the Hirota bilinear method, the homogeneous balance method and the tanh method [1]-[32]. Moreover, Kudryashov proposed (G'/G)-expansion method to obtain some new exact traveling wave solutions of PDEs [33], which is effective.

In this paper, we will use the novel $(\frac{G'}{G})$-expansion method[34] to receive some new exact solutions for the following generalized Davey-Stewartson equations with arbitrary power nonlinearities[35]:

$$\begin{cases} iu_t + u_{xx} + u_{yy} + \gamma|u|^p u + \alpha uv + \delta|u|^{2p}u = 0, \\ v_{xx} + v_{yy} - \beta(|u|^p)_{xx} = 0. \end{cases} \tag{1.1}$$

where $\alpha, \beta, \gamma, \delta$ are real parameters, p is a positive integer, v is a real function, u is a complex function. Generalized Davey-Stewartson equation with arbitrary power nonlinearities is effective, which describes the short-wave and long-wave motion in water with limited depth. Many researchers have applied a lot of methods for solving Eq.(1.1). For example, Ming Song[35] and Cao Jun[36] used the bifurcation method of dynamical systems to obtain the traveling wave solutions for Eq.(1.1). M Mirzazadeh applied the trial equation method and the ansatz approach to establish solitary waves soliton, dark soliton and singular solitary waves soliton solutions of the Davey-Stewartson equation[37]. Ming Song studied the Davey-Stewartson equation with power law nonlinearity and carried out several different solutions for the bifurcation analysis[38]. Reza Farshbaf Zinati used He's semi-inverse variational principle method (SIVPM), the improved $\tan(\phi/2)$-expansion method (ITEM) and generalized (G'/G)-expansion method (GGM) for seeking more exact solutions of the DS equation[39]. The generalized Kudryashov method is introduced to obtain new soliton solutions of the Davey-Stewartson equation with power law nonlinearity by Seyma Tuluce Demiray[40]. Mehdi Fazli Aghdaei applied the generalized $\tan(\phi/2)$ method and He's semi-inverse variational method (HSIVM) to seek the exact solitary wave solutions of the Davey-Stewartson equation with power law nonlinearity[41].

This paper is organized as follows: In sections 2, we mainly describe the novel $(\frac{G'}{G})$-expansion method. In sections 3, we apply this method to solve Eq.(1.1). Some conclusions are given in sections 4.

2 Description of the Novel $(\frac{G'}{G})$-Expansion Method

Consider the following nonlinear PDEs:

$$P(t, x_i, u_t, u_{x_i}, u_{x_i x_i}, u_{x_i x_j}, u_{tt}, ...), \tag{2.1}$$

where $i, j, = 1, 2, ..., n$. P is a polynomial in $u(x,t)$, $u(x,t)$ is an unknown function. The main steps of the novel $(\frac{G'}{G})$-expansion method are as follows:

Step 1. Make a transformation:

$$u(t, x_1, u_2, \cdots, u_n) = \phi(\xi), \xi = \sum_{i=1}^{n} k_i x_i - ct. \tag{2.2}$$

Eq.(2.1) can be reduced to the following nonlinear ordinary differential equations(ODEs):

$$Q(u, u', u'', u''', ...) = 0, \tag{2.3}$$

where Q is a function of $u(\xi)$ and its derivatives.

Step 2. Suppose the solution of Eq.(2.3) can be denoted by a polynomial in $\psi(\xi)$:

$$u(\xi) = \sum_{j=-n}^{n} \alpha_j (\psi(\xi))^j, \tag{2.4}$$

where

$$\psi(\xi) = d + \frac{G'(\xi)}{G(\xi)}. \tag{2.5}$$

The constants α_{-n} and α_n could not be zero simultaneously. $\alpha_j (j = 0, \pm 1, \pm 2, ..., \pm N)$ and d are constants.

Step 3. Consider the second order nonlinear ODE:

$$GG'' = \lambda GG' + \mu G^2 + v(G')^2, \tag{2.6}$$

where prime denotes the derivative with respect ξ. λ, μ and c are real parameters.

The Cole-Hopf transformation $\Phi(\xi) = \frac{G'(\xi)}{G(\xi)}$ reduces Eq.(2.6)to the following equation:

$$\Phi'(\xi) = \mu + \lambda \Phi(\xi) + (c-1)\Phi^2(\xi) \tag{2.7}$$

Thus, Eq.(2.7) has individual twenty five solutions (see[42]).

Step 4. The value of the positive integer n can be determined by balancing the higher order linear terms with nonlinear terms of the higher order occurring in Eq.(2.3).

Step 5. Substitute Eq.(2.4) along with Eq.(2.5)and Eq.(2.6)into Eq.(2.3). Then, obtain polynomials in $(d + \frac{G'(\xi)}{G(\xi)})$ and $(d + \frac{G'(\xi)}{G(\xi)})^{-1}, (j = 0, 1, 2, ..., N)$. Furthermore, collect the coefficients of the resulted polynomials to be zero and receive a system of algebraic equations by Maple. Finally, we deserve the exact solutions of Eq.(2.3).

3 Applications of Novel (G'/G)-Expansion Method

In this section, we use the novel (G'/G)-expansion method to solve Eq.(1.1). First, we suppose Eq.(1.1) as follows:

$$u(x,y,t)=f(\xi)e^{i\eta}, v(x,y,t)=f_0(\xi), \tag{3.1}$$

where $\xi=x+y-2(k+\lambda)t$, $\eta=kx+\lambda y-wt$. λ,k,w are real parameters, $f(\xi)$ is real function.

Making Eq.(3.1) into Eq.(1.1), then letting real and imaginary part be zero respectively:

$$\begin{cases}(w-k^2-\lambda^2)f+2f''+\gamma f^{p+1}+\alpha f f_0+\delta f^{2p+1}=0,\\ f_0=\frac{\beta}{2}f^p.\end{cases} \tag{3.2}$$

Substituting the second equation of (3.2) into the first equation of (3.2), we obtain

$$f''=-\frac{1}{2}\delta f^{2p+1}-\frac{1}{2}(\gamma+\frac{\alpha\beta}{2})f^{p+1}+\frac{1}{2}(\lambda^2+k^2-w)f. \tag{3.3}$$

For simplification, we draw

$$f''+k_5f^5+k_3f^3+k_1f=0, \tag{3.4}$$

where $k_5=\frac{1}{2}\delta$, $k_3=\frac{1}{2}(\gamma+\frac{\alpha\beta}{2})$, $k_1=-\frac{1}{2}(\lambda^2+k^2-w), p=1$. From Eq.(3.4), we obtain

$$p\Phi''+q\Phi+2\Phi^3=0 \tag{3.5}$$

where $p=\dfrac{2}{k_3}, q=\dfrac{2k_1}{k_3}$. Substituting (3.1) into (3.5) and balancing the higher order derivative u'' with the nonlinear term of the highest order u^3, we receive $n=1$. Thus, the solution of Eq.(3.5) have

$$u(\xi)=\alpha_{-1}(\Psi(\xi))^{-1}+\alpha_0+\alpha_1(\Psi(\xi)). \tag{3.6}$$

Inserting Eq.(3.6) into Eq.(3.5), the left hand side becomes polynomials of $(d+\dfrac{G'(\xi)}{G(\xi)})$ and $(d+\dfrac{G'(\xi)}{G(\xi)})^{-1}, (j=0,1,2,...,N)$. Setting the coefficients of these polynomials to be zero, we deserve a set of algebraic equations for $\alpha_1,\alpha_0,\alpha_{-1},d$ and c as follows:

$$(\frac{G'}{G})^6: 2p\alpha_1(v-1)^2+2\alpha_1^3=0,$$

$$(\frac{G'}{G})^5: p[3\alpha_1\lambda(v-1)+6\alpha_1 d(v-1)^2]+2(6d\alpha_1^3+3\alpha_0\alpha_1^2)=0,$$

$$\begin{aligned}(\frac{G'}{G})^4: &p[\alpha_1(2\mu v-2\mu+\lambda^2)+6\alpha_1 d\lambda(v-1)+6\alpha_1 d^2(v-1)^2]+2(15d^2\alpha_1^3+15d\alpha_0\alpha_1^2\\ &+3\alpha_1^2\alpha_{-1}+3\alpha_1\alpha_0^2)+q\alpha_1=0,\end{aligned}$$

$$\begin{aligned}(\frac{G'}{G})^3: &p[\alpha_1\lambda\mu+3\alpha_1 d(2\mu v-2\mu+\lambda^2)+(9\lambda\alpha_1 d^2+\alpha_{-1}\lambda)(v-1)+2(v-1)^2(\alpha_1 d^3\\ &-\alpha_{-1}d)]+2(20d^3\alpha_1^3+30d^3\alpha_0\alpha_1^2+12d\alpha_1^2\alpha_{-1}+12d\alpha_0^2\alpha_1+6\alpha_0\alpha_1\alpha_{-1}\\ &+\alpha_0^3)+q=0,\end{aligned}$$

$$\begin{aligned}(\frac{G'}{G})^2: &p[3\alpha_1 d\lambda\mu+(3\alpha_1 d^2+\alpha_{-1})(2\mu v-2\mu+\lambda^2)+3\lambda(v-1)(\alpha_1 d^3-\alpha_{-1}d)]\\ &+2[15d^4\alpha_1^3+30d^3\alpha_0\alpha_1^2+18d^2\alpha_{-1}\alpha_1^2+18d^2\alpha_1\alpha_0^2+18d\alpha_{-1}\alpha_0\alpha_1\\ &+3d\alpha_0^2+3\alpha_1\alpha_{-1}^2+3\alpha_{-1}\alpha_0^2]+q(\alpha_0+3\alpha_0 d+6\alpha_1 d^2)=0,\end{aligned}$$

$$(\frac{G'}{G})^1 : p[3\alpha_1\lambda\mu d^2 + 3\alpha_{-1}\lambda\mu + (2\mu v - 2\mu + \lambda^2)(\alpha_1 d^3 - \alpha_{-1}d)] + 2[6d^5\alpha_1^3 + 15\alpha_0\alpha_1^2 d^4$$
$$+12\alpha_{-1}\alpha_1^2 d^3 + 12\alpha_1\alpha_0^2 d^3 + 18\alpha_1\alpha_0\alpha_{-1}d^2 + 3\alpha_0^3 d^2 + 6\alpha_1\alpha_{-1}^2 d + 6\alpha_{-1}\alpha_0^2 d$$
$$+3\alpha_0\alpha_{-1}^2] + q[2\alpha_1 d + 3\alpha_0 d^2 + 4\alpha_1 d^3] = 0,$$
$$(\frac{G'}{G})^0 : p[\lambda\mu(\alpha_1 d^3 - \alpha_{-1}d) + 2\alpha_{-1}\mu^2] + 2[\alpha_1^3 d^6 + 3\alpha_0\alpha_1^2 d^5 + 3\alpha_{-1}\alpha_1^2 d^4 + 3\alpha_1\alpha_0^2 d^4$$
$$+6\alpha_0\alpha_1\alpha_{-1}d^3 + \alpha_0^3 d^3 + 3\alpha_1\alpha_{-1}^2 d^2 + 3\alpha_{-1}\alpha_0^2 d^2 + 3\alpha_0\alpha_{-1}^2 d + \alpha_{-1}^3] + q(\alpha_1 d^2$$
$$+\alpha_0 d^3 + \alpha_1 d^4) = 0.$$

Solving the algebraic equations by Maple ,we obtain
Case 1:

$$\alpha_1 = \pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1) - 2\lambda^2}}$$
$$\alpha_0 = \pm(\lambda - 2d(v-1))\sqrt{\frac{q}{8\mu(v-1) - 2\lambda^2}}$$
$$\alpha_{-1} = 0$$
$$p = \frac{-2q}{4\mu(v-1) - \lambda^2}$$
$$d = d \tag{3.7}$$

Case 2:

$$\alpha_1 = 0$$
$$\alpha_0 = \pm(\lambda - 2d(v-1))\sqrt{\frac{q}{8\mu(v-1) - 2\lambda^2}}$$
$$\alpha_{-1} = \pm 2(d^2(v-1) + \mu - \lambda d)\sqrt{\frac{q}{8\mu(v-1) - 2\lambda^2}}$$
$$p = \frac{-2q}{4\mu(v-1) - \lambda^2}$$
$$d = d \tag{3.8}$$

Case 3:

$$\alpha_1 = \pm(v-1)\sqrt{\frac{q}{8\mu(v-1) - 2\lambda^2}}$$
$$\alpha_0 = 0$$
$$\alpha_{-1} = \mp\frac{\sqrt{q(4\mu(v-1) - \lambda^2)}}{4\sqrt{2}(v-1)}$$
$$p = \frac{-q}{8\mu(v-1) - 2\lambda^2}$$

$$d = \frac{\lambda}{2(v-1)} \tag{3.9}$$

Case 4:

$$\alpha_1 = \pm(v-1)\sqrt{\frac{-2q}{8\mu(v-1)-2\lambda^2}}$$

$$\alpha_0 = 0$$

$$\alpha_{-1} = \mp\frac{\sqrt{-4q\mu(v-1)-q\lambda^2}}{4(v-1)}$$

$$p = \frac{q}{4\mu(v-1)-\lambda^2}$$

$$d = \frac{\lambda}{2(v-1)} \tag{3.10}$$

where p, q, d, λ, μ and v are arbitrary constants.

Substituting (3.7)-(3.10) into solution Eq.(3.5), we derive

$$u_1(z,t) = \pm(\lambda - 2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$
$$\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}(d + (G'/G)) \tag{3.11}$$

where $\xi = az \mp \sqrt{\frac{4\mu(v-1)-\lambda^2-2q}{4\mu(v-1)-\lambda^2}}t$, p, q, d, λ, μ and v are arbitrary constants.

$$u_2(z,t) = \mp(\lambda - 2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$
$$\pm 2(d^2(v-1)+\mu-\lambda d)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}(d + (G'/G))^{-1} \tag{3.12}$$

where $\xi = az \mp \sqrt{\frac{4\mu(v-1)-\lambda^2-2q}{4\mu(v-1)-\lambda^2}}t$, p, q, d, λ, μ and v are arbitrary constants.

$$u_3(z,t) = \pm(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}(\frac{\lambda}{2(v-1)} + (G'/G))$$
$$\pm\frac{\sqrt{q(4\mu(v-1)-\lambda^2)}}{4\sqrt{2}(v-1)}(\frac{\lambda}{2(v-1)} + (G'/G))^{-1} \tag{3.13}$$

where $\xi = az \mp \sqrt{\frac{8\mu(v-1)-2\lambda^2-q}{8\mu(v-1)-2\lambda^2}}t$, p, q, d, λ, μ and v are arbitrary constants.

$$u_4(z,t) = \pm(v-1)\sqrt{\frac{-2q}{8\mu(v-1)-2\lambda^2}}(\frac{\lambda}{2(v-1)} + (G'/G))$$
$$\mp\frac{\sqrt{-4q\mu(v-1)-q\lambda^2}}{4(v-1)}(\frac{\lambda}{2(v-1)} + (G'/G))^{-1} \tag{3.14}$$

where $\xi = az \mp \sqrt{\frac{4\mu(v-1)-\lambda^2+q}{4\mu(v-1)-\lambda^2}}t$, p, q, d, λ, μ and v are arbitrary constants.

Substituting the value of (G'/G) into Eq.(3.14), we obtain solutions of Eq.(1.1) as follows:
When $\Omega = \lambda^2 - 4\mu v + 4\mu > 0$, $\lambda(v-1) \neq 0$ (or $\mu(v-1) \neq 0$), we have

$$u_{1_1}(z,t) = \pm(\lambda - 2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \times\{d - \frac{1}{2(v-1)}(\lambda + \sqrt{\Omega}tanh(\frac{1}{2}\sqrt{\Omega}\xi))\} \tag{3.15}$$

$$u_{1_2}(z,t) = \pm(\lambda - 2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \times\{d - \frac{1}{2(v-1)}(\lambda + \sqrt{\Omega}coth(\frac{1}{2}\sqrt{\Omega}\xi))\} \tag{3.16}$$

$$u_{1_3}(z,t) = \pm(\lambda - 2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \times\{d - \frac{1}{2(v-1)}(\lambda + \sqrt{\Omega}(tanh(\sqrt{\Omega}\xi) \pm isech(\sqrt{\Omega}\xi)))\} \tag{3.17}$$

$$u_{1_4}(z,t) = \pm(\lambda - 2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \times\{d - \frac{1}{2(v-1)}(\lambda + \sqrt{\Omega}(coth(\sqrt{\Omega}\xi) \pm csch(\sqrt{\Omega}\xi)))\} \tag{3.18}$$

$$u_{1_5}(z,t) = \pm(\lambda - 2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \times\{d - \frac{1}{4(v-1)}(2\lambda + \sqrt{\Omega}(tanh(\frac{1}{4}\sqrt{\Omega}\xi) + coth(\frac{1}{4}\sqrt{\Omega}\xi)))\} \tag{3.19}$$

$$u_{1_6}(z,t) = \pm(\lambda - 2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \times\{d + \frac{1}{2(v-1)}(-\lambda + \frac{\pm\sqrt{\Omega(m_1^2+m_2^2)} - m_1\sqrt{\Omega}cosh(\sqrt{\Omega}\xi)}{m_1 sinh(\sqrt{\Omega}\xi) + m_2})\} \tag{3.20}$$

$$u_{1_7}(z,t) = \pm(\lambda - 2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \times\{d + \frac{1}{2(v-1)}(-\lambda + \frac{\pm\sqrt{\Omega(m_1^2+m_2^2)} + m_1\sqrt{\Omega}cosh(\sqrt{\Omega}\xi)}{m_1 sinh(\sqrt{\Omega}\xi) + m_2})\} \tag{3.21}$$

where m_1 and m_2 are real non-zero constants.

$$u_{1_8}(z,t) = \pm(\lambda - 2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \times\{d + \frac{2\mu cosh(\frac{1}{2}\sqrt{\Omega}\xi)}{\sqrt{\Omega}sinh(\frac{1}{2}\sqrt{\Omega}\xi) - \lambda cosh(\frac{1}{2}\sqrt{\Omega}\xi)}\} \tag{3.22}$$

$$u_{1_9}(z,t) = \pm(\lambda - 2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}} \times\{d + \frac{2\mu sinh(\frac{1}{2}\sqrt{\Omega}\xi)}{\sqrt{\Omega}cosh(\frac{1}{2}\sqrt{\Omega}\xi) - \lambda sinh(\frac{1}{2}\sqrt{\Omega}\xi)}\} \tag{3.23}$$

$$u_{1_{10}}(z,t)=\pm(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$
$$\times\{d+\frac{2\mu cosh(\sqrt{\Omega}\xi)}{\sqrt{\Omega}sinh(\sqrt{\Omega}\xi)-\lambda cosh(\sqrt{\Omega}\xi)\pm i\sqrt{\Omega}}\} \tag{3.24}$$

$$u_{1_{11}}(z,t)=\pm(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$
$$\times\{d+\frac{2\mu sinh(\sqrt{\Omega}\xi)}{\sqrt{\Omega}cosh(\sqrt{\Omega}\xi)-\lambda sinh(\sqrt{\Omega}\xi)\pm\sqrt{\Omega}}\} \tag{3.25}$$

When $\Omega=\lambda^2-4\mu v+4\mu<0$, $\lambda(v-1)\neq 0$ (or $\mu(v-1)\neq 0$), we have

$$u_{1_{12}}(z,t)=\pm(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$
$$\times\{d+\frac{1}{2(v-1)}(-\lambda+\sqrt{-\Omega}tan(\frac{1}{2}\sqrt{-\Omega}\xi))\} \tag{3.26}$$

$$u_{1_{13}}(z,t)=\pm(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$
$$\times\{d-\frac{1}{2(v-1)}(\lambda+\sqrt{-\Omega}cot(\frac{1}{2}\sqrt{-\Omega}\xi))\} \tag{3.27}$$

$$u_{1_{14}}(z,t)=\pm(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$
$$\times\{d-\frac{1}{2(v-1)}(-\lambda+\sqrt{-\Omega}(tan(\sqrt{-\Omega}\xi)\pm sec(\sqrt{-\Omega}\xi)))\} \tag{3.28}$$

$$u_{1_{15}}(z,t)=\pm(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$
$$\times\{d-\frac{1}{2(v-1)}(\lambda+\sqrt{-\Omega}(cot(\sqrt{-\Omega}\xi)\pm csc(\sqrt{-\Omega}\xi)))\} \tag{3.29}$$

$$u_{1_{16}}(z,t)=\pm(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$
$$\times\{d+\frac{1}{4(v-1)}(-2\lambda+\sqrt{-\Omega}(tan(\frac{1}{4}\sqrt{-\Omega}\xi)-cot(\frac{1}{4}\sqrt{-\Omega}\xi)))\} \tag{3.30}$$

$$u_{1_{17}}(z,t)=\pm(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$
$$\times\{d+\frac{1}{2(v-1)}(-\lambda+\frac{\pm\sqrt{-\Omega(m_1^2-m_2^2)}-m_1\sqrt{-\Omega}cos(\sqrt{-\Omega}\xi)}{m_1 sin(\sqrt{-\Omega}\xi)+m_2})\} \tag{3.31}$$

$$u_{1_{18}}(z,t)=\pm(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$
$$\times\{d+\frac{1}{2(v-1)}(-\lambda+\frac{\pm\sqrt{-\Omega(m_1^2-m_2^2)}+m_1\sqrt{-\Omega}cos(\sqrt{-\Omega}\xi)}{m_1 sin(\sqrt{-\Omega}\xi)+m_2})\} \tag{3.32}$$

where m_1 and m_2 are arbitrary constants such that $p^2-q^2>0$.

$$u_{1_{19}}(z,t)=\pm(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$

$$\times\{d-\frac{2\mu cos(\frac{1}{2}\sqrt{-\Omega}\xi)}{\sqrt{-\Omega}sin(\frac{1}{2}\sqrt{-\Omega}\xi)+\lambda cos(\frac{1}{2}\sqrt{-\Omega}\xi)}\} \tag{3.33}$$

$$u_{1_{20}}(z,t)=\pm(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$

$$\times\{d+\frac{2\mu sin(\frac{1}{2}\sqrt{-\Omega}\xi)}{\sqrt{-\Omega}cos(\frac{1}{2}\sqrt{-\Omega}\xi)-\lambda sin(\frac{1}{2}\sqrt{-\Omega}\xi)}\} \tag{3.34}$$

$$u_{1_{21}}(z,t)=\pm(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$

$$\times\{d-\frac{2\mu cos(\sqrt{-\Omega}\xi)}{\sqrt{-\Omega}sin(\sqrt{-\Omega}\xi)+\lambda cos(\sqrt{-\Omega}\xi)\pm\sqrt{\Omega}}\} \tag{3.35}$$

$$u_{1_{22}}(z,t)=\pm(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$

$$\times\{d+\frac{2\mu sin(\frac{1}{2}\sqrt{-\Omega}\xi)}{\sqrt{-\Omega}cos(\frac{1}{2}\sqrt{-\Omega}\xi)-\lambda sin(\frac{1}{2}\sqrt{-\Omega}\xi)\pm\sqrt{\Omega}}\} \tag{3.36}$$

When $\mu=0$ and $\lambda(v-1)\neq 0$,

$$u_{1_{23}}(z,t)=\pm(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$

$$\times\{d-\frac{\lambda k}{(v-1)(k+cosh(\lambda\xi)-sinh(\lambda\xi))}\} \tag{3.37}$$

$$u_{1_{24}}(z,t)=\pm(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$

$$\times\{d-\frac{\lambda(cosh(\lambda\xi)+sinh(\lambda\xi))}{(v-1)(k+cosh(\lambda\xi)+sinh(\lambda\xi))}\} \tag{3.38}$$

where k is an arbitrary constant.

Similarly, substituting the value of (G'/G) into Eq.(3.15), we achieve the solutions of Eq.(1.1):

When $\Omega=\lambda^2-4\mu v+4\mu>0$, $\lambda(v-1)\neq 0$ (or $\mu(v-1)\neq 0$), we get

$$u_{2_1}(z,t)=\mp(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(d^2(v-1)+\mu-\lambda d)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$

$$\times\{d-\frac{1}{2(v-1)}(\lambda+\sqrt{\Omega}tanh(\frac{1}{2}\sqrt{\Omega}\xi))\}^{-1} \tag{3.39}$$

$$u_{2_2}(z,t)=\mp(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(d^2(v-1)+\mu-\lambda d)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$

$$\times\{d-\frac{1}{2(v-1)}(\lambda+\sqrt{\Omega}coth(\frac{1}{2}\sqrt{\Omega}\xi))\}^{-1} \tag{3.40}$$

$$u_{2_3}(z,t)=\mp(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(d^2(v-1)+\mu-\lambda d)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$

$$\times\{d-\frac{1}{2(v-1)}(\lambda+\sqrt{\Omega}(tanh(\sqrt{\Omega}\xi)\pm isech(\sqrt{\Omega}\xi)))\}^{-1} \tag{3.41}$$

The other families of exact solutions of Eq.(1.1) are omitted for convenience.

When $\Omega=\lambda^2-4\mu v+4\mu<0$, $\lambda(v-1)\neq 0$ (or $\mu(v-1)\neq 0$), we get

$$u_{2_{12}}(z,t)=\mp(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(d^2(v-1)+\mu-\lambda d)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$
$$\times\{d+\frac{1}{2(v-1)}(-\lambda+\sqrt{-\Omega}tan(\frac{1}{2}\sqrt{-\Omega}\xi)))\}^{-1} \tag{3.42}$$

$$u_{2_{13}}(z,t)=\mp(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(d^2(v-1)+\mu-\lambda d)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$
$$\times\{d-\frac{1}{2(v-1)}(\lambda+\sqrt{-\Omega}cot(\frac{1}{2}\sqrt{-\Omega}\xi)))\}^{-1} \tag{3.43}$$

The other families of exact solutions of Eq.(1.1) are omitted for convenience.

When $\mu=0$ and $\lambda(v-1)\neq 0$,

$$u_{2_{23}}(z,t)=\mp(\lambda-2d(v-1))\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\pm 2(d^2(v-1)+\mu-\lambda d)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}$$
$$\times\{d-\frac{\lambda k}{(v-1)(k+cosh(\lambda\xi)-sinh(\lambda\xi))}\}^{-1} \tag{3.44}$$

where k is an arbitrary constant.

The other families of exact solutions of Eq.(1.1) are omitted for convenience.

Again, substituting the value of (G'/G) into Eq.(3.16), we achieve the solutions Eq.(1.1):

When $\Omega=\lambda^2-4\mu v+4\mu>0$, $\lambda(v-1)\neq 0$ (or $\mu(v-1)\neq 0$), we receive

$$u_{3_1}(z,t)=\pm(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\times\{\frac{\lambda}{2(v-1)}-\frac{1}{2(v-1)}(\lambda+\sqrt{\Omega}tanh(\frac{1}{2}\sqrt{\Omega}\xi))\}$$
$$\pm\frac{\sqrt{q(4\mu(v-1)-\lambda^2)}}{4\sqrt{2}(v-1)}\times\{\frac{\lambda}{2(v-1)}-\frac{1}{2(v-1)}(\lambda+\sqrt{\Omega}tanh(\frac{1}{2}\sqrt{\Omega}\xi))\}^{-1} \tag{3.45}$$

$$u_{3_2}(z,t)=\pm(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\times\{\frac{\lambda}{2(v-1)}-\frac{1}{2(v-1)}(\lambda+\sqrt{\Omega}coth(\frac{1}{2}\sqrt{\Omega}\xi))\}$$
$$\pm\frac{\sqrt{q(4\mu(v-1)-\lambda^2)}}{4\sqrt{2}(v-1)}\times\{\frac{\lambda}{2(v-1)}-\frac{1}{2(v-1)}(\lambda+\sqrt{\Omega}coth(\frac{1}{2}\sqrt{\Omega}\xi))\}^{-1} \tag{3.46}$$

The other families of exact solutions of Eq.(1.1) are omitted for convenience.

When $\Omega=\lambda^2-4\mu v+4\mu<0$, $\lambda(v-1)\neq 0$ (or $\mu(v-1)\neq 0$), we receive

$$u_{3_{12}}(z,t)=\pm(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\times\{\frac{\lambda}{2(v-1)}+\frac{1}{2(v-1)}(-\lambda+\sqrt{-\Omega}tan(\frac{1}{2}\sqrt{-\Omega}\xi))\}$$
$$\pm\frac{\sqrt{q(4\mu(v-1)-\lambda^2)}}{4\sqrt{2}(v-1)}\times\{\frac{\lambda}{2(v-1)}+\frac{1}{2(v-1)}(-\lambda+\sqrt{-\Omega}tan(\frac{1}{2}\sqrt{-\Omega}\xi))\}^{-1} \tag{3.47}$$

$$u_{3_{13}}(z,t)=\pm(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\times\{\frac{\lambda}{2(v-1)}-\frac{1}{2(v-1)}(\lambda+\sqrt{-\Omega}cot(\frac{1}{2}\sqrt{-\Omega}\xi))\}$$

$$\pm\frac{\sqrt{q(4\mu(v-1)-\lambda^2)}}{4\sqrt{2}(v-1)}\times\{\frac{\lambda}{2(v-1)}-\frac{1}{2(v-1)}(\lambda+\sqrt{-\Omega}cot(\frac{1}{2}\sqrt{-\Omega}\xi))\}^{-1} \quad (3.48)$$

The other families of exact solutions of Eq.(1.1) are omitted for convenience.

When $\mu=0$, $\lambda(v-1)\neq 0$, we receive

$$u_{3_{23}}(z,t)=\pm(v-1)\sqrt{\frac{q}{8\mu(v-1)-2\lambda^2}}\times\{\frac{\lambda}{2(v-1)}-\frac{\lambda k}{(v-1)(k+cosh(\lambda\xi)-sinh(\lambda\xi))}\}$$

$$\pm\frac{\sqrt{q(4\mu(v-1)-\lambda^2)}}{4\sqrt{2}(v-1)}\times\{\frac{\lambda}{2(v-1)}-\frac{\lambda k}{(v-1)(k+cosh(\lambda\xi)-sinh(\lambda\xi))}\}^{-1} \quad (3.49)$$

where k is an arbitrary constant.

The other families of exact solutions of Eq.(1.1) are omitted for convenience.

Finally, substituting the value of (G'/G) into Eq.(3.17), we achieve the solutions Eq.(1.1):

When $\Omega=\lambda^2-4\mu v+4\mu>0$, $\lambda(v-1)\neq 0$ (or $\mu(v-1)\neq 0$), we know

$$u_{4_1}(z,t)=\pm(v-1)\sqrt{\frac{-2q}{8\mu(v-1)-2\lambda^2}}\times\{\frac{\lambda}{2(v-1)}-\frac{1}{2(v-1)}(\lambda+\sqrt{\Omega}tanh(\frac{1}{2}\sqrt{\Omega}\xi))\}$$

$$\mp\frac{\sqrt{-4q\mu(v-1)-q\lambda^2}}{4(v-1)}\times\{\frac{\lambda}{2(v-1)}-\frac{1}{2(v-1)}(\lambda+\sqrt{\Omega}tanh(\frac{1}{2}\sqrt{\Omega}\xi))\}^{-1} \quad (3.50)$$

$$u_{4_2}(z,t)=\pm(v-1)\sqrt{\frac{-2q}{8\mu(v-1)-2\lambda^2}}\times\{\frac{\lambda}{2(v-1)}-\frac{1}{2(v-1)}(\lambda+\sqrt{\Omega}coth(\frac{1}{2}\sqrt{\Omega}\xi))\}$$

$$\mp\frac{\sqrt{-4q\mu(v-1)-q\lambda^2}}{4(v-1)}\times\{\frac{\lambda}{2(v-1)}-\frac{1}{2(v-1)}(\lambda+\sqrt{\Omega}coth(\frac{1}{2}\sqrt{\Omega}\xi))\}^{-1} \quad (3.51)$$

The other families of exact solutions of Eq.(1.1) are omitted for convenience.

When $\Omega=\lambda^2-4\mu v+4\mu<0$, $\lambda(v-1)\neq 0$ (or $\mu(v-1)\neq 0$), we know

$$u_{4_{12}}(z,t)=\pm(v-1)\sqrt{\frac{-2q}{8\mu(v-1)-2\lambda^2}}\times\{\frac{\lambda}{2(v-1)}+\frac{1}{2(v-1)}(-\lambda+\sqrt{-\Omega}tan(\frac{1}{2}\sqrt{-\Omega}\xi))\}$$

$$\mp\frac{\sqrt{-4q\mu(v-1)-q\lambda^2}}{4(v-1)}\times\{\frac{\lambda}{2(v-1)}+\frac{1}{2(v-1)}(-\lambda+\sqrt{-\Omega}tan(\frac{1}{2}\sqrt{-\Omega}\xi))\}^{-1} \quad (3.52)$$

$$u_{4_{13}}(z,t)=\pm(v-1)\sqrt{\frac{-2q}{8\mu(v-1)-2\lambda^2}}\times\{\frac{\lambda}{2(v-1)}-\frac{1}{2(v-1)}(\lambda+\sqrt{-\Omega}cot(\frac{1}{2}\sqrt{-\Omega}\xi))\}$$

$$\mp\frac{\sqrt{-4q\mu(v-1)-q\lambda^2}}{4(v-1)}\times\{\frac{\lambda}{2(v-1)}-\frac{1}{2(v-1)}(\lambda+\sqrt{-\Omega}cot(\frac{1}{2}\sqrt{-\Omega}\xi))\}^{-1} \quad (3.53)$$

The other families of exact solutions of Eq.(1.1) are omitted for convenience.

When $\mu=0$ and $\lambda(v-1)\neq 0$, we know

$$u_{4_{23}}(z,t)=\pm(v-1)\sqrt{\frac{-2q}{8\mu(v-1)-2\lambda^2}}\times\{\frac{\lambda}{2(v-1)}-\frac{\lambda k}{(v-1)(k+cosh(\lambda\xi)-sinh(\lambda\xi))}\}$$

$$\mp\frac{\sqrt{-4q\mu(v-1)-q\lambda^2}}{4(v-1)}\times\{\frac{\lambda}{2(v-1)}-\frac{\lambda k}{(v-1)(k+cosh(\lambda\xi)-sinh(\lambda\xi))}\}^{-1} \quad (3.54)$$

where k is an arbitrary constant.

The other families of exact solutions of Eq.(1.1) are omitted for convenience.

4 Conclusion

In this paper, we have used the novel $(\frac{G'}{G})$-expansion method to obtain some exact traveling wave solutions for generalized Davey-Stewartson equations with arbitrary power nonlinearities. Comparing the results with the effective result of [35]-[41] by Maple, we know that our results are new. Hence, the performance of this method is reliable. Finally, it also can be applied to solve other nonlinear PDEs for deriving some new exact solutions.

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