PROVISIONAL PATENT APPLICATION

Title of the Invention

Parallel Plasma Stabilizer for Fusion Devices Using the Pinch Effect

Field of the Invention

The present invention relates to plasma physics and nuclear fusion technology. More particularly, it concerns methods and apparatus for improving plasma stability in fusion devices that utilize the pinch effect, including but not limited to Z-pinch reactors and toroidal confinement systems such as tokamaks.

Background of the Invention

Most plasma fusion devices rely on the pinch effect, as described by the equations formulated by Willard Harrison Bennett. The pinch effect refers to the magnetic compression of an electrically conducting filament—typically plasma—caused by the magnetic field generated by an electric current flowing through it. This self-induced magnetic field forces charged particles inward, resulting in plasma compression, heating, and confinement.

This phenomenon, also known as the Bennett pinch, was a foundational concept in early nuclear fusion research, particularly in Z-pinch configurations. However, such systems are prone to significant instabilities, which limit confinement time and energy gain. As a result, additional magnetic confinement methods are commonly required, especially in curvilinear plasma configurations such as tokamak reactors.

In these fusion devices, plasma can be approximated as a linear structure, either straight (as in Z-pinch reactors) or curvilinear (as in tokamaks). Fusion is pursued by generating extremely high pulsed electric currents through the plasma, inducing the pinch effect and causing plasma compression (implosion). In tokamak systems, plasma stability is further supported by externally applied strong magnetic fields.

The ultimate goal of plasma compression is to achieve nuclear fusion with a positive energy balance, meaning that the energy produced by fusion reactions exceeds the electrical energy supplied by the excitation pulses. For this condition to be met, plasma stability and sustained confinement over sufficient time intervals are essential.

Extensive experimental and operational experience has demonstrated that, alongside the desired pinch-induced implosion, plasma disruption phenomena (explosive behaviors) frequently arise. These instabilities counteract confinement, limit plasma lifetime, and significantly hinder fusion performance.

Summary of the Problem

Based on detailed studies and experiments conducted on metallic structures that are electromagnetically equivalent to plasma, the inventor has identified a primary source of plasma instability. This instability arises from shear forces caused by the excessive concentration of electrons at the geometric center of the plasma column.

This electron concentration is attributed to the quantum behavior of plasma when excited by harmonic frequency components present in the pulsed electric currents used in fusion devices. These harmonics induce non-uniform charge distributions, leading to internal shear stresses that destabilize the plasma and trigger disruptive phenomena.

Summary of the Invention

The present invention proposes the addition of a parallel stabilizing structure, functioning as a harmonic filtering system, electrically coupled in parallel with the plasma column in fusion devices.

This parallel structure is designed to divert and absorb the harmonic components of the pulsed excitation currents, thereby preventing these harmonics from interacting with the plasma. By suppressing the influence of these harmonic frequencies, the invention reduces electron concentration at the plasma center, mitigates shear forces, and significantly improves plasma stability.

The invention applies to both linear and curvilinear plasma configurations and is compatible with existing fusion device architectures.

Detailed Description of the Invention

The proposed plasma stabilization system comprises a parallel electrical structure connected across the plasma load. This structure may be implemented in several exemplary but non-limiting embodiments, including the following:

1. Capacitive Harmonic Absorption Network

A network of capacitors electrically connected to form a total capacitance C, selected such that the total capacitive reactance at frequencies f—corresponding to wavelengths approximately equal to the plasma length—is several thousand times smaller than the plasma’s effective resistive impedance Rp.

This condition is expressed as:

$$1 / (2\pi f C) \ll R_p$$

Under this condition, harmonic currents preferentially flow through the parallel capacitive structure rather than through the plasma.

2. High-Voltage Compatibility

The parallel structure is designed to withstand the full operational voltage of the plasma excitation system, including high-voltage pulsed currents used to induce the pinch effect.

3. Semiconductor-Based Harmonic Suppression

In certain embodiments, the parallel structure further includes semiconductor components (such as diodes or controlled electronic devices) configured to prevent secondary harmonic excitation generated within the parallel structure itself from coupling back into the plasma.

4. Equivalent Electronic Implementations

Any equivalent electronic circuit composed exclusively of electronic components—including but not limited to diodes, triodes, or solid-state devices—that functionally emulate the harmonic filtering behavior of the capacitive network is considered within the scope of the invention.

Advantages of the Invention

The invention provides multiple technical advantages, including but not limited to:

- Suppression of plasma-destabilizing harmonic excitations

- Reduction of electron overconcentration at the plasma core

- Mitigation of shear-induced plasma instabilities

- Increased plasma confinement time

- Improved likelihood of achieving a positive fusion energy balance

- Compatibility with existing and future fusion reactor designs

Conclusion

By introducing a parallel harmonic-filtering structure electrically coupled to the plasma, the present invention addresses a fundamental and persistent source of plasma instability in fusion devices employing the pinch effect. This approach enhances plasma stability without interfering with the primary fusion-driving current, thereby representing a novel and practical advancement in nuclear fusion technology.