Hybrid supercapacitor (HSC) are becoming increasingly significant in energy storage due to their outstanding electrochemical properties, with the selection of electrode material being a critical determinant of their performance. Owing to their porous nature, adaptable morphologies, enhanced tunability, and varied chemical compositions, metal-organic frameworks (MOFs) have been utilized as electrode materials in hybrid supercapacitors. This study synthesized a nickel-based metal-organic framework (Ni-MOF) using 5-sulfoisophthalic acid sodium salt and 1,10-phenanthroline as organic linkers and nickel as the metal center through a sonochemical process to assess its efficacy as a hybrid supercapacitor electrode material. Thorough characterization methods, such as FTIR, TGA, and UV-Vis, validated the existence of functional groups, molecular structure, thermal stability, and optical characteristics of the synthesized Ni-MOF. The electrochemical properties of the synthesized Ni-SSIPA-MOF were examined using galvanostatic charge/discharge (GCD) studies, cyclic voltammetry (CV), and electrochemical impedance spectroscopy (EIS) in a 1 M KOH electrolyte using an electrochemical workstation. The Ni-SSIPA-MOF demonstrated exceptional pseudocapacitive performance, achieving specific capacity and capacitances of 301.38 C/g and 547.97 F/g at a current density of 1.25 A/g in a three-electrode configuration. The HSC utilizing Ni-SSIPA-MOF as the activated carbon (AC) for the negative electrode attained an energy density of 8.5 Wh/kg, a power density of 354.16 W/kg, with a coulombic efficiency of 101 % after 10,000 cycles, underscoring Ni-SSIPA-MOF as a promising electrode material in hybrid supercapacitors. A semi-empirical technique employing Dunn's model and power law is utilized to validate results by examining the capacitive and diffusive contributions, as well as the b-values.