Phase change materials (PCMs) generally suffer from low thermal conductivity which limits their application in thermal systems. The effective thermal conductivity may be improved by including fins, metallic powders, fine wires, and nanoparticles. The objective of this study is to investigate the thermal performance of graphene nanoplatelets (GNPs) dispersed in small quantities in 1-tetradecanol ($C_{14}H_{30}O$) PCM. This nano-enhanced PCM (NPCM) is placed in the annular space of a shell and tube in a solar thermal storage unit. The numerical simulations have been carried out using a numerical model based on the enthalpy-porosity and the control volume methods. The numerical model has been successfully validated by comparison with experimental data available in the literature. The numerical results showed that the higher the GNPs concentration, the lower the stored energy. The higher the GNPs concentration the shorter the discharging time. But, during the charging process, though the reduction in the melting time by 9.5% for GNPs concentration increase from 0 to 1 wt%, the melting time increased in contrast by 10.5% for GNPs content increasing from 1 to 3 wt%. For the GNPs concentration of 3 wt%, the heat transfer rate enhancement was limited by an undesirable increase in viscosity which led to weak natural convection and hence a longer charging time. Thus, the GNPs concentration of 1 wt% showed better thermal performance than that of 3 wt% concentration. These results may guide the improvement of solar thermal storage by dispersing GNPs in PCM.