Whey protein based gelling systems may present several functional roles in food formulations by enhancing textural properties (e.g. mouthfeel), acting as stabilizing agents or by being used as carrier of bioactive substances (e.g. nutraceuticals). The rates and pathways for the production of a protein gel system are controlled by heating conditions, protein concentration, pH, ionic strength, and solvent medium. The combination of heat and electric treatment has the potential to interfere with unfolding and aggregation of whey proteins and thus with protein–protein interactions. The general objective of this study was to evaluate and understand the effects of electric fields (EF) during thermal aggregation of liquid dispersions of whey protein isolate (WPI) and hydrogels made thereof. The main goal of this study was to induce thermal aggregation of a liquid dispersion of WPI into a three-dimensional network, a so called hydrogel, through combined application of instantaneous heating and EF. Nanostructures and nano–scale phenomena of the initial steps of whey protein aggregation were assessed by nano–tracking analysis and dynamic light scattering techniques. To assess the effects of EF on macroscopic properties of the produced hydrogels, rheological measurements were performed under steady shear flow. This study shows that EF interferes with inter– and intra–molecular protein interactions producing a marked reduction in whey protein aggregation. This particle size reduction can be controlled by the intensity of electrical treatment applied (e.g. EF treatments of 0, 3 and 10 V/cm have determined particle sizes of 156.9, 141.1 and 117.7 nm, respectively). The rheological measurements show that apparent viscosity of the produced hydrogels is also affected by the presence and magnitude of the EF applied. In conclusion, EF induces changes from a nanometer to micrometer range offering a great potential to the development of GRAS (generally recognized as safe) engineered nanotechnology–based delivery systems for food applications.