Nonlocal field theory of dipolar particles in electrolyte solutions: Debye-Hueckel theory extension

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A nonlocal statistical field theory of a dilute electrolyte solution with small additive of dipolar particles will be discussed. We will postulate that with every dipolar particle is associated an arbitrary probability distribution function (PDF) of distance between its charge centers. Using the standard Hubbard-Stratonovich transformation, we will represent the configuration integral of the system in the functional integral form. We will demonstrate that in the limit of a small permanent dipole moment, the functional in integrand exponent takes the well known form of the Poisson-Boltzmann-Langevin (PBL) functional. In the mean-field approximation we will obtain a non-linear integro-differential equation with respect to the mean-field electrostatic potential, generalizing the PBL equation for the point-like dipoles obtained first by Abrashkin et al. We will apply the obtained equation in its linearized form to derivation of the expressions for the mean-field electrostatic potential of the point-like test ion and its solvation free energy in salt-free solution, as well as in solution with salt ions. We will get a general relation for the bulk electrostatic free energy of the solution in the framework of the Random phase approximation.