In order to realize maximum power output of photovoltaics (PV), reduce line losses, and decrease abandoned solar energy during weak irradiance, a new medium voltage grid-connected PV system structure based on cascaded converters was proposed in this paper. A transformerless cascade step-up structure, instead of applying line-frequency step-up transformer, is proposed to connect PV directly to the 10 kV medium voltage grid. This series-connected step-up PV system integrates with multiple functions, including separated maximum power point tracking (MPPT), centralized energy storage, power quality regulation. Its inherent excellent features makes it not only adapt to different geographical and environmental installing conditions, but also to improve converter efficiency and flexibility. This paper focuses on the analyses of system structure design, control principle and strategy, and then comparing the performance of different PV plant structures, including central, multi-string and this novel series-connected structure. Additionally, by properly choosing storage battery capacity in accordance with the demand of power grid and load, this structure is able to achieve short-term power grid support and peak-load shifting.