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Abstract The enhanced penetration of available renewable energy sources (RES) is preferred over-utilizing the maximum cost budget for the conventional power system operation. Severe uncertainty and power generation and load demand balance are the pre and post-challenges of RES penetration respectively. Penetration of RES can be made effective by modeling the RES uncertainty with a computationally efficient technique and controlling the load demand smartly. In this paper for the smooth and stable penetration of RES, the uncertainty of RES is modeled using the sympathetic impact of information gap decision theory (SI-IGDT) to deal with minimum possible uncertainty. Smart demand response (SDR) is modeled using a virtual layer as a smart demand response operator (SDO) between the main grid and consumers for the post-challenge of RES penetration. The SDO categorizes consumers into virtual prosumer (VP), real prosumer seller (RPS), and real prosumer buyer (RPB) using a power flow conditional algorithm (PFCA). The uncertainty of RES is subsequently optimized and implemented using the firefly optimization algorithm (FOA) and the power flow algorithm (PFA). To achieve technical and economic benefits for the main grid and all consumers, a Stackelberg game is formulated using PFCA and multi-objective FOA (MFOA). MATLAB is used for the implementation of the algorithms and the test system. Simulation results show that the maximum available RES power is penetrated up to 300%, and load demand reduction is observed up to 62% which ultimately reduces the power flow loss by 70%.

Keywords Firefly algorithm, Information gap decision theory, Renewable energy sources, Smart demand response, Stackelberg game.