**INFORMATION ABOUT RESEARCH RESULTS**

Dissertation title: **Expanding the distribution generation and energy storage system on the distribution network**

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**1. Summary of content**

In each country, electricity plays an increasingly important role in ensuring stability and development. Currently, energy is in short supply due to increasing energy demand as well as environmental factors. Distribution and load networks will change in the coming years with new requirements and challenges such as services, reliability, investment costs, energy prices and environmental factors. Therefore, with new requirements, the distribution network needs to be expanded. To expand the distribution network, it is possible to upgrade lines, build new lines, install new substations, expand substation capacity, install Distributed Generation (DG), expand DG capacity, Energy Storage System (ESS) installation. The renovation and upgrade of the line, the construction of a new line, the installation of more substations or the upgrading of systems to serve at certain times of high load will increase investment capital, increase costs and not effective. Currently, the expansion of the distribution network through the installation of DG or ESS to support the power system is an inevitable trend.

The energy strategy focuses on exploiting renewable energy and natural gas sources, saving energy, storing energy and attracting investment policies. Sustainable energy like solar, wind and energy storage is said to be very efficient. These technologies are gaining popularity because of their drastically reduced costs and support for many policies. Therefore, it is necessary to install and exploit DG into the system in order to achieve technical, economic and environmental benefits. ESS is growing and its use in distributed networks is increasingly common. ESS helps the system operate efficiently such as avoiding contract penalties due to power outages, reducing energy prices, responding to sudden electricity price increases, reducing dependence on Renewable Energy Sources (RES) and delaying invest in upgrading the existing power system. Therefore, it is necessary to study and install ESS for distribution networks to improve operational efficiency. Among the types of ESS, the Battery Energy Storage System (BESS) is commonly used in the distribution network today.

In the current situation, some distribution networks have been installed with low-cost renewable DGs, mostly photovoltaic (PV). Because of the installation location, environmental factors, incentive policies and the ability of investors, it is difficult for PVs to choose the optimal location and capacity for installation.In practice, the PVs are partially installed according to the existing investment conditions and continue to expand the capacity depending on the actual conditions. Therefore, the distribution grid needs to determine the optimal operating configuration for the system to operate at the highest efficiency. DG and ESS attract many researchers in the problem of optimizing location and capacity to expand the distribution network and improve system operating efficiency. When the distribution network expands with DG and ESS, the system will work more efficiently, control the purchase price of electricity and reduce environmental factors. Therefore, some problems to expand the distribution network need to be solved as follows:

- For the distribution network without DG: The expansion of the distribution network through determining the location and capacity of the DG participating in the system in order to improve the system's operational efficiency. In which, the power loss minimization is the main factor in the optimal objective function because the power loss minimization shows the efficiency of the DG participating in the system.

- For distribution networks that already have DG (mainly PV): Continued expansion of PV capacity in the same or new location according to investment capabilities, incentive policies, installation location and weaknesses. factors affecting the environment. At this time, the distribution network needs to redefine the new operating configuration of the distribution network with the objective function of minimizing energy loss.

- For a distribution network with high electricity purchase costs, it is necessary to reduce electricity purchase costs, or for a distribution network with DG of Renewable Energy Sources (RES) with unstable output power, it is necessary to exploit the power efficiency. fruit. Expansion of operating capacity of ESS in addition to electricity price reduction, RES exploitation reduces energy loss, time shifting and load peak reduction are also considered. At this point, it is necessary to determine the location and capacity of the ESS in order for the distribution network to operate with the great benefits of ESS.

- For the distribution network that needs to exploit the potential of local energy sources: The expansion of the distribution network needs to maximize the participating capacity of DG and reduce the cost of DG investment. In system operation, one of the important technical issues to reduce costs is minimizing power loss. At this time, the problem needs to maximize the power of the DG and reduce the power loss.

 From the research works as well as practice the topic *"Expanding the distributed generation and energy storage system on the distribution network"* with the goal of solving the problem of expanding the distribution network through the installation of DG /ESS as follows:

* Expansion of distribution network through new installation of DG considering Distribution Network Reconfiguration (DNR) with the objective function of minimizing system power loss.
* Determine the operating configuration of the distribution network when DG continues to be expanded with the objective function of minimizing energy loss.
* Expansion of distribution network through new installation of ESS with the objective function of reducing the cost of purchasing electricity and reducing the cost of energy loss.
* Extend the penetration power of the DG into the distribution network with the objective function of minimizing power loss.

**2. New contributions of the topic**

The thesis analyzes and proposes the problem of expanding the distribution network, expanding the capacity of the DG and the capacity of the ESS to improve the operating efficiency of the distribution network. The thesis proposes three new problems and one problem applied to the distribution network of Vietnam as follows:

**Problem 1:** Expanding the distribution network through determining the optimal location and capacity of the DG with consideration of Distribution Network Reconfiguration (DNR). The thesis presents a new problem to solve the problem of optimal position and capacity of DG through two stages. Phase I - optimal installation of DG in closed loops (design phase) and phase II - optimization of open switch for open grid operation (operation phase). The proposed problem is to optimize the installation of DG considering DNR with the objective function of minimizing the power loss of the system. The two-stage proposed problem is a new type of optimization problem in DG setting optimization with DNR in addition to the problem of location, capacity and DNR (concurrency problem) and optimization problem. position optimization first, then power and DNR optimization (VT- CS and DNR problems). The proposed problem with two optimization stages has the advantage of providing a globally optimal solution to the DG installation problem with consideration of reconfiguration. The two-stage problem shows that the number of variables decreases for each stage of the optimization algorithm by dividing it into two stages. In addition, the proposed two-phase problem also shows that it is suitable for long-term DG installation (design phase) to be given priority and DNR to be short-term (operating phase). The 33-node distribution network and the 69-node distribution network were tested and showed the effectiveness of the proposed problem. The proposed problem uses Runner Root Algorithm (RRA) algorithm to perform and compare with Coyote Algorithm (COA) and Genetic Algorithm (GA). In terms of algorithms, the results show that RRA, COA and GA algorithms are effective algorithms to optimize DG installation for distribution network with DNR. The proposed problem is also compared with the concurrent problems and the VT- CS and DNR problems with different algorithms also show the efficiency of the two-phase separation problem. The simulation results of the proposed problem show that the power loss of the whole system is similar to the concurrency problem and better than that of the VT-CS and DNR problems.

**Problem 2:** Determine the configuration of the distribution network when expanding the capacity of photovoltaic (PV). The thesis proposes an improved branch exchange algorithm with average branch capacity (CSNTB) to determine the operating configuration of the distribution network when PV is expanded with the goal of minimizing energy loss. The advantage of the proposed problem is that it is simple, easy to implement and accurate in determining the configuration of the distribution network when the PV is expanded to the installed capacity. The 18-node distribution network and 33-node distribution network have been tested, showing that the proposed method is simple, quickly determines the grid configuration and has high accuracy when compared to the problem of determining the configuration. Distribution network according to the method of using average branch capacity (CSNTB) and the method of using load graph by optimization algorithms.

 **Problem 3:** Applying to expand the distribution network of Chu Prong - Gia Lai, Vietnam. Chu Prong distribution network is applied to expand through DG installation in order to maximize the penetration capacity and minimize the power loss of the system. The problem proposes three stages of DG installation, corresponding to three locations and feasible capacity that can be installed in the Chu Prong distribution grid. Runner Root Algorithm (RRA) and Coyote Algorithm (COA) algorithms are effectively used for problem 1 and are applied to test the problem of installing three DGs for Chu Prong distribution network. From the results of three optimized DGs, the thesis proposes a plan to expand DG installation for Chu Prong distribution network through three phases in order to suit the investment and installation of DG in the shortest time.

**Problem 4:** Expanding the distribution network through the installation of a Battery Energy Storage System (BESS) to reduce the cost of purchasing energy. The thesis presents the problem of determining the location and capacity of BESS on the distribution network in order to reduce the cost of purchasing electricity as well as the cost of energy loss. The proposed problem with a new point is to give an objective function that is to minimize the cost of purchasing energy and the CSA algorithm is applied for the first time to the problem of optimizing the location and capacity of BESS. Optimizing the installation of BESS into the system not only reduces the cost of purchasing electricity, but also reduces energy loss and effectively exploits renewable energy systems (RES). The 18-node distribution network and the 33-node distribution network with PV were tested for the BESS installation optimization problem and showed the effectiveness of BESS when participating in the distribution grid.

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