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Research Article

INVESTIGATION OF THE EFFECTS OF TRANSMISSION SYSTEM COOPERATION OPERATORS IN ELECTRIC ENERGY NETWORKS

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ABSTRACT

The structure of common networks, physically and legally, is such that they are centrally exploited and there is no issue as the common use of electrical energy systems. In re-structured networks, asset management and the efficient use of electrical energy equipment requires some kind of close cooperation between entities that use electrical energy systems. The collaboration and interaction between distribution system operators and transmission systems, or both, can have a significant impact on issues such as restructuring, the electricity market, distributed generation and demand management, etc. However, the main impact of this interaction is on cost management. Therefore, such cooperation and interactions in energy networks will also improve network efficiency and reduce costs. To this end, issues such as challenges and frameworks for cooperation data between system operators and their areas should be carefully considered. The results show that this collaboration will save time and money in addition to network upgrades.

Keywords: cooperation, network, transmission system operators, wind farm

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INTRODUCTION

Distribution System Operator means an individual or law that is responsible for implementing, ensuring proper maintenance, operation, developing a Distribution System in a specific area and linking it to other systems, where necessary. The transmission system operator, in the wholesale power market, manages the management of the power system in real-time. It also coordinates the supply and demand of electricity in a way that avoids frequency fluctuations or interruptions. Transmission system operators are usually regarded in the law as part of the electricity market [3]. Therefore, the actions taken by transmission system operators have no effect on the performance of distribution system operators (except for emergencies where major discharge should take place). The development of demand-side response, coupled with the growing influence of distributed generation on their networks, is becoming a major challenge for distribution system operators [15]. Unlike the past when electric currents were predictable, nowadays due to the emergence of scattered production, electric vehicles, electric storage devices, etc., electric currents are not predictable. For this reason, the distribution system operators will have to manage new loads and change current roles [5]. It can be said that new cooperation is dependent on the information and operations of distributed generation resources. It is, therefore, necessary to define how information system operators receive distributed generation resources information (directly or through any other agent) and how requests are sent to these resources (directly or through any other agent). In summary, new cooperation requires determining which agent or representative is directly related to distributed generation resources (or receive information or send requests) and how the new connection between system operators is [5]. To facilitate sufficient technical performance in the global power system, the interactions between the technical performance of the distribution and the main transmission networks require the exchange of information, which aids both network operators. Distribution system operators are currently unable to access the data and measuring them with the help of the transmission system operator, and if this access is too small, data cooperation will be difficult and sampling accuracy will be very low. This means that the available measurement data is too limited [1]. Ideally, the exchange of information between network operators should be more accurate and compact near the boundary between transmission and distribution networks. Because in adjacent networks, the actions taken by the transmission and distribution system operator can severely affect each other's network planning performance and activities [8]. When the two operators work together, the tasks of each of them will change dramatically. The distribution system operator needs to obtain information and control over the connection point between the network operators. Its main purpose is to facilitate the creation of a domestic, efficient, competitive and sustainable energy market that works for public resources. In 2014, a documentary examining the role of distribution system operators in light of future changes due to the emergence of dispersed energy sources is presented, and the results show that improvements in infrastructure, strengthening and development of exchanged data between transmission system operators and Distribution can lead to efficiency and cost savings for the end consumer [14]. The Wisconsin Energy Institute says that as a dispersed energy source market and contributes to grid ancillary services, the boundaries of transmission and distribution operators are fading. The Institute's report studies the relationship between transmission and distribution operators, as a key aspect of the coordination between the two operators. Therefore, operator interaction reporting has the benefits of reducing potential losses, increasing system reliability and minimizing carbon dioxide emissions [5]. Previous studies have shown that, from a practical perspective, it is not desirable to concentrate full system responsibility on distribution system operators, since the process of full coordination becomes very complex. But the responsible system for distribution system operators must be expanded to access all the redistribution resources in the distribution network. This is becoming increasingly important as the share of renewable energy sources in the electricity system increases. In short, not only coordination is a key to addressing future challenges, but also is the source of proper allocation of resources to system operators. The results also show that more robust and complete collaboration between systems, operators can have significant cost savings in addition to having a positive impact on the performance of both operators [12]. The role of the distribution system operators is evolving due to the increasing penetration of alternative and distributed energy sources in the distribution system. On the one hand, transmission system operators have access to flexible resources connected to the distribution network. Distribution system operators, on the other hand, are actively managing network distribution congestion, far from the common and forgotten approach. As a result, the need for a co-operation between the distribution system operator and the transmission system operator has become increasingly important. Studies show that cooperation between distribution system operators as well as between distribution system operators and microgrids can be crucial in the long run due to the development of local energy markets [7]. Due to power grids and power systems, there is a trend of increasing penetration and reuse of distributed energy sources. Distributed energy sources can provide services to both the distribution system and transmission system operators. Distributed power sources are usually installed and connected to power grids, which may be fully controlled or monitored by power system operators. If renewable energy sources operate to provide system services or market actions, this may lead to system benefits and efficiency improvement, but it can be accompanied by technical, economic and legal challenges. Distribution and transmission system operators must be able to coordinate, monitor and send resources as well as study and share information promptly [3]. In Ref. [10], the collaboration between the transmitting system and the distribution system is analyzed to balance the power system power balance, thus the sample network state is simulated. The purpose of this study was to optimize the economic use of network flexibility due to known limitations. For this purpose, two optimization problems are presented: The optimal deployment of facilities to support retransmission attempts and optimal use of available units as secondary storage in the specific ancillary services scheme. To discuss different types of networks, technical changes, as well as price and market structure, the parameters related to its optimization, are first determined. In [12] presents common challenges associated with the transmission system operators and distribution system operators, as well as the need for a strong correlation between them in the environment of segregated power systems. The results show that the exchange of information between the transmission system operator and the distribution system operator contributes to improving the level of penetration of renewable energy sources and also enables the system operators to significantly increase the security of the short and long term system. One of the studies on the cooperation of operators is the German Case project. 50Hertz Transmission GmbH is one of the four transmission system operators in Germany. The operator offers new responsibilities and requirements for system operators about the smart grid. This document defines the responsibilities of both system operators in their country. The results of the study indicate that collaboration among market players is a key issue for future network designs. In legal terms, this document lacks clear terms and conditions for the collection, presentation, and use of smart grid data [5]. The results of the REservise project implemented in Germany show that determining the reactive power flow requirements within the communication range of the two system operators causes the system to fail. If the distribution system operators are allowed to use their ancillary services and network management in collaboration with the system operators, the result can be more efficient and less costly [5]. The Irish Distribution Company is developing a pilot project in which transmission and distribution system operators must constantly interact with aggregators on the requirements of distributed energy sources, which is a requirement for the operation of distributed energy sources. When each of the service system operators buys, the aggregator decides which agents can participate. The advantage of this template is that both system operators have all the services provided by network users. The disadvantage of this approach is that transmission or distribution system operators can provide services that may impose new constraints on the other operator's network [5].

METHODS

Each is considered to investigate the influence of cooperation and interaction of network transfer operators under consideration, and the network specifications and costs of the network before and after the formation of the operators and the transformer cooperation.

Schematic of the studied network

The network simulated by MATLAB in this study is shown in Fig.1.

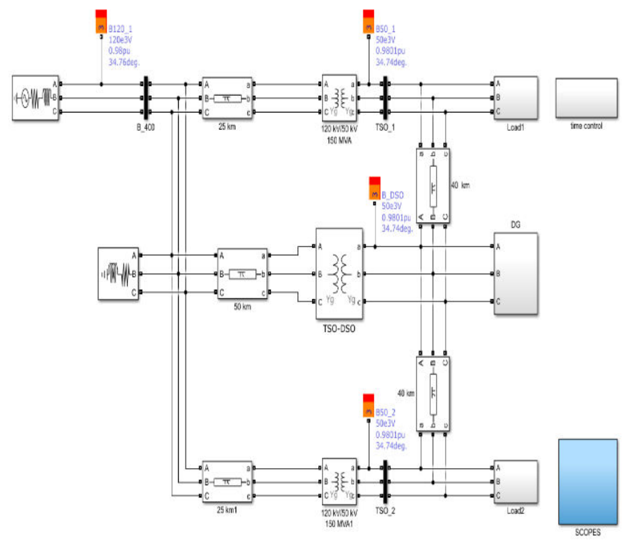

Fig. 1. Schematic overview of the grid

Network specifications

In this network, the cooperation between the two operators of the transmission system takes place. Loads 1 and 2 are used as time-varying loads used by a time controller to generate loads on a day-to-day basis. Their specifications are listed in Table 1.

Table.1 Load specifications

Hours	load connected to the transmission 1 (load 1) in MW network	load connected to the transmission 2(load 2) in MW network
1	23.29	23.29
3	18.63	31.73
5	42.89	14.36
7	31.80	33.59
9	41.66	18.63
11	9.31	41.66
13	35.81	42.89
15	24.29	24.29
17	33.59	15.02
19	14.36	32.94
21	27.95	9.31
23	15.02	35.81

For a detailed examination of the cooperation, the conditions of both the

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transmission operator are considered the same. For this purpose, the length of the transmission lines for both operators is 25 km. There is also a fixed load capacity of 50 MW per hour between the two transmission lines. Both transmission lines are 40 km apart with three-phase power generators. A 150-megawatt three-phase power generator is intended as the primary power plant at the beginning of the grid.
In this study, the distributed generation source and transformer are considered as devices that can be shared. The wind farm's generation capacity is connected to the grid by a 25/20 KV incremental transformer with a power of 200 MV and a common transformer with a 25/50 KV and 100 MV power. The wind farm consists of 11 induction generator turbines with an output voltage of 575 volts each. The output power of the wind farm is about 90 MW.
The simulation of this network is done in two stages. In the first phase, the turbines are separated from the grid when the three-phase switch is open. At this point, the amount of power generated by each system operator is checked. In the second phase, by closing the switch, the distributed generation source and transformer enter the circuit to be shared between the two operators of a given network transmission system. Fig.2 shows the characteristic curve of the wind turbine production in terms of wind speed corresponding to the 10 kW rotors.

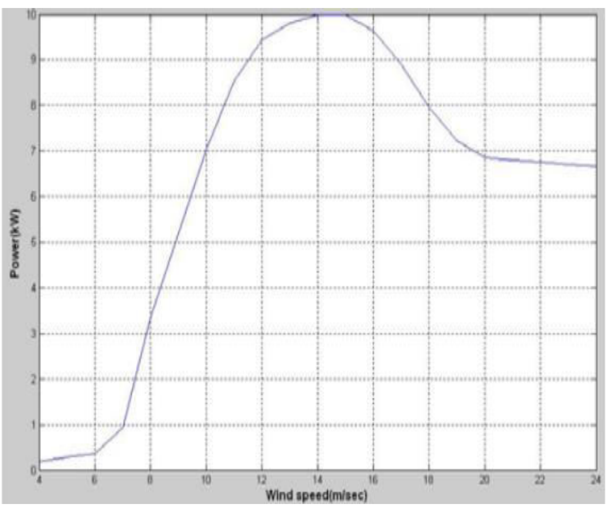

Fig.2. 10 kW wind turbine characteristic curve (Power rate in terms of wind speed) [2]

Functions used
In this section, we examine the objective function, economic relationships, and costs governing the source of wind power generation. The source used related costs include construction costs and replacement costs. To optimize the power system, the total annual costs must be calculated. The following relationships are defined to calculate the costs associated with the project lifetime:

- Interest rate:

$$i = \frac{\left(\acute{i}-f\right)}{\left(1+f\right)} \qquad (1)$$

In relation (1), i is the nominal interest rate and f is the annual inflation rate. In this study, the nominal interest rate is 20 and the annual inflation rate is 12.

- Return factor of capital

$$CRF\left(i, R_{proj}\right) = \frac{i\left(1+i\right)^{R_{proj}}}{\left(1+i\right)^{R_{proj}}-1} \qquad (2)$$

That R_{proj} is the length of the project and it's been considered 50 years.

- Cost replacement time

$$R_{rep} = R_{comp}.INT\left(\frac{R_{proj}}{R_{comp}}\right) \qquad (3)$$

Where R_{comp} is the lifetime of each resource. In this study, 20 years are considered.

- A residual lifetime of each resource

$$R_{rem} = R_{comp} - \left(R_{proj} - R_{rep}\right) \qquad (4)$$

- Return factor of capital according to the replacement period

$$CRF\left(i, R_{rep}\right) = \frac{i\left(1+i\right)^{R_{rep}}}{\left(1+i\right)^{R_{rep}}-1} \qquad (5)$$

- Lifetime-related factor

$$f_{rep}\left\{\begin{matrix} \dfrac{CRF\left(i, R_{proj}\right)}{CRF\left(i, R_{rep}\right)}; R_{rep} > 0 \\ 0; R_{rep} < 0 \end{matrix}\right\} \qquad (6)$$

- Depreciation factor of capital according to resource lifetime

$$SSF\left(i, R_{comp}\right) = \frac{i}{\left(1+i\right)^{R_{comp}}-1} \qquad (7)$$

Now we look at the existing costs:

- Annual investment costs

$$C_{acap} = C_{cap}.CRF\left(i - R_{proj}\right) \qquad (8)$$

Where C_{cap} is the initial investment cost of the resources, which is estimated at 10,000 $.

- Annual replacement cost

$$C_{arep} = C_{rep}\left\{f_{rep}.SSF\left(i, R_{comp}\right) - \frac{R_{rem}}{R_{comp}}.SSF\left(i, R_{proj}\right)\right\} \qquad (9)$$

Where C_{rep} is the cost of replacing each resource. Fig.3 is used to

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calculate C_{rep} and C_{cap} for wind sources, where the costs of wind sources are given in terms of the number of modules.

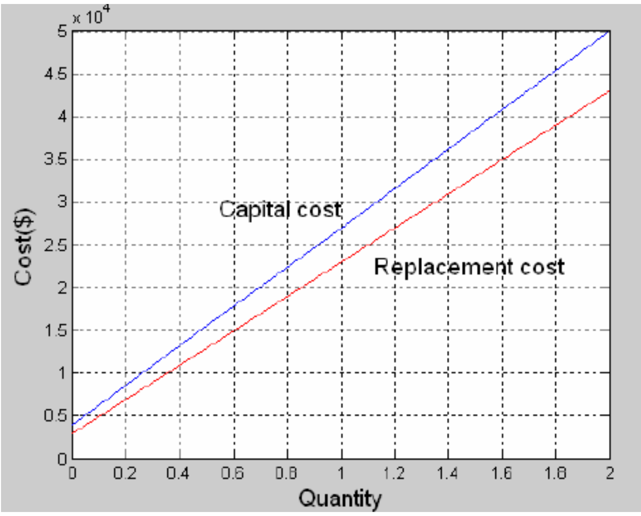

Fig.3. The cost curve for wind turbines

After defining the available costs, we now consider the objective function of the system, which is to minimize all available costs. The objective function is (10).

$$Cost = \sum_{i=0}^{3} (C_{arepi} + C_{acapi} + C_{ao\&mi} \qquad (10)$$

Where is the annual maintenance and maintenance cost of 10,000 $.
A genetic algorithm is used in cases where absolute optimality is not considered and near enough set of optimal points.

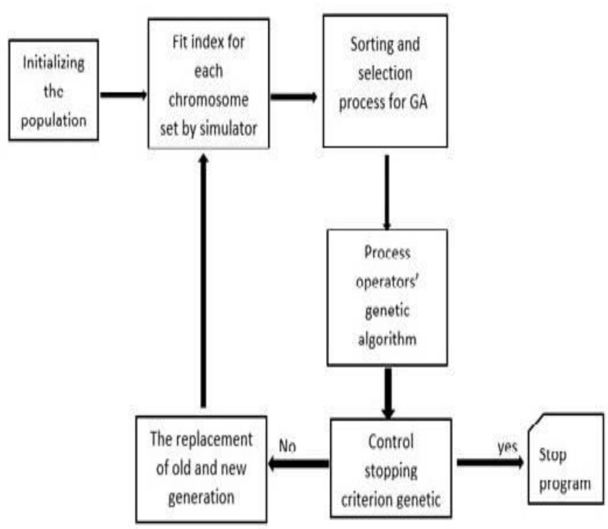

Fig.4. The general process of solving the optimization problem with the genetic algorithm

As shown in Fig.4, the operators of the genetic algorithm are selected, intersection, and mutation. The fit of each chromosome is the inverse of the value of its objective function, which is calculated as (11).

$$Fitness_i = \frac{1}{Cost_i} \qquad (11)$$

Two-point crossover operator with a mutation probability of 0.2% was used for each chromosome. The use of a two-point intersection operator is to avoid the choice of optimal local solutions.

RESULTS AND DISCUSSION

Network specifications

In the first case of simulation, the source of the scattered production has not entered the circuit and no cooperation has taken place. In non-cooperation mode, with all constant and variable loads in circuits, Tables 2 and 3show the amount of power shortages that system operators face.

Table 2. Transmission System Operator Power Loss No. 1

Power failure hours	Generating Power (MW)	Power Consumption by the load (MW)	Power Outage (MW)
7	31.77	33.59	1.89
11	34.26	41.66	7.4
13	28.66	42.89	14.23
15	17.93	24.29	6.36
19	14.54	32.96	18.4

Table 3.Transmission System Operator Power Loss No. 2

Power failure hours	Generating Power (MW)	Power consumption by the load (MW)	Power Outage (MW)
7	29.6	31.80	2.2
9	36.19	41.66	5.47
13	28.66	35.81	7.15
17	18.66	33.59	14.93
21	17.49	27.59	10.46

Fig.5 to Fig.7 show the increase in the main (upstream) bus production capacity, respectively, of Transmission Operators 1 and 2 after cooperation with a distributed generation source and the transformer instead of two separate sources of transmission generation.

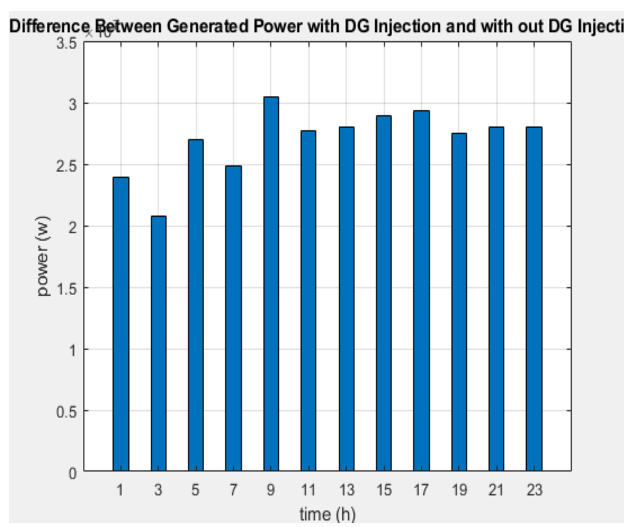

Fig.5. Main Bass Power Generation by Wind Farm cooperation

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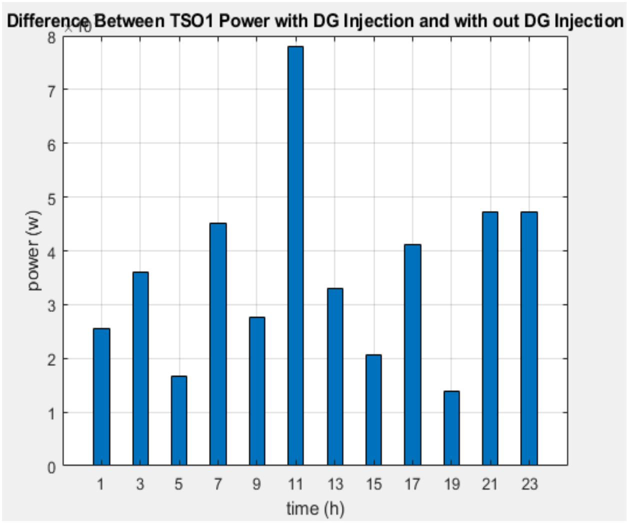

Fig.6. The power generated by the operator transmission system number 1 after cooperation

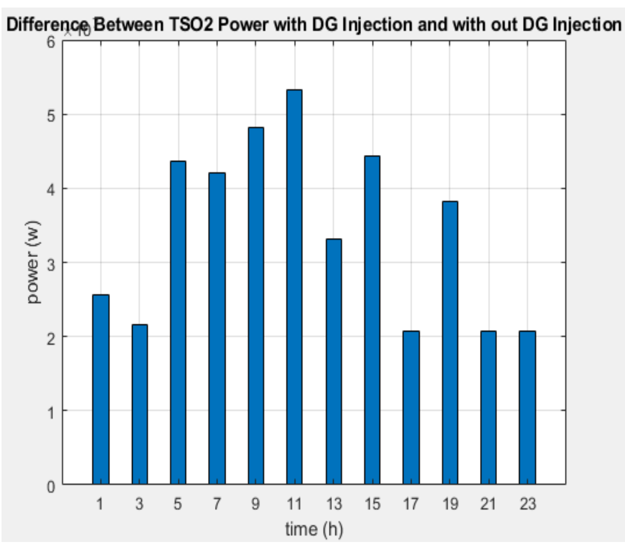

Fig.7. The power generated by the operator transmission system number 2 after cooperation

Simulation economic evaluation results

Based on the average power requirements for a day and night for Operators 1 and 2, respectively, in normal conditions, 65 and 53 megawatts of power is needed to solve their grid power shortage problem. This amount of power loss, given that the output power of each turbine requires 8 and 6 turbines, respectively. Emergency 2 turbines will be added to the number of turbines needed to meet the load shortage. Therefore, the number of turbines required for operator 1 and 2 in emergencies is 10 and 8, respectively. According to Fig.8 the transmission system operator No. 1 will have to pay 45,400 $, assuming it operates in a network emergency and requires the construction of 10 9-megawatt turbines. However, transmission system operator No. 2 will have to pay 36,200 $ to build 8 9-megawatt turbines. Therefore, it can be said that the whole network will incur 81600 $ in compensation for the shortage of available power. Fig.9 shows the construction cost of transmission system operators 1 and 2 and their sum.

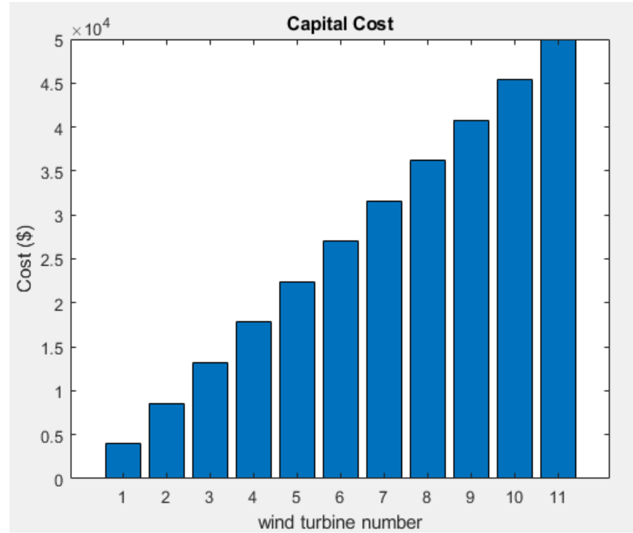

Fig. 8.Cost of investment and construction of wind turbines

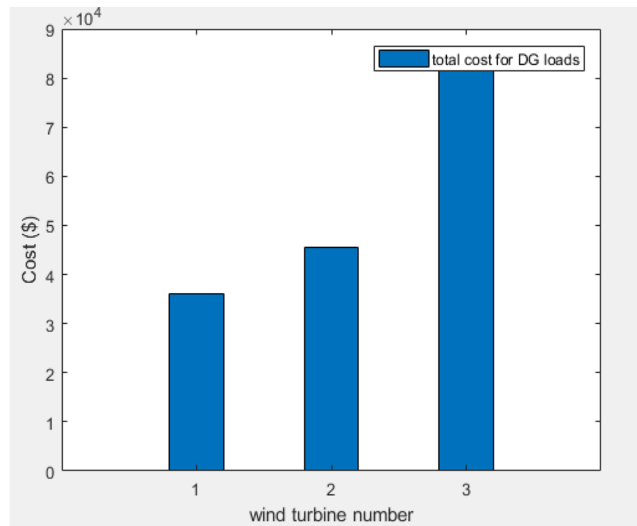

Fig.9.Cost of construction of wind turbines needed before cooperation

The sharing of a wind farm that was technically able to offset power shortages with 11 wind turbines with 9-megawatt power costs 50,000 $. So it turns out that sharing of the wind farm has been able to save 31,600 $. In the normal state of the network (the absence of an emergency), the operator of the transmission system number 1 needs 8 wind turbines and the operator of the transmission system number 2 needs 6 wind turbine numbers. The total cost is 63200 $, which will be decreased by 13200 $ by cooperation. Fig.10 shows that the emergency replacement cost for Operator No. 1 is 41700 $ and Operator No. 2 is 33100 $, which is a total of 74800 $. After cooperation this cost is reduced to 46,000 $, in fact, 28,800 $ has been saved. Normally, the cost of Transmission Operator No. 1, Transmission Operator No. 2 and the network total are, respectively, 33100, 24500 and 57600. So 11600 $ in economic savings has been earned.

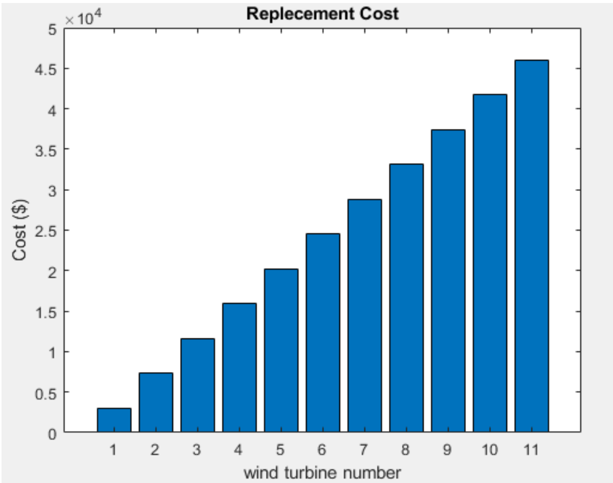

Fig.10. Cost of wind turbine replacement

CONCLUSION

Sharing of a distributed generation source significantly increases the production capacity of the main bus and transmission system operators, which can also account for the potential new loads that may arise in the future. In normal states, the capital cost is dropped by 21% and network emergency by 39%. Regarding replacement costs, about 20 percent are in normal and about 38 percent of emergency savings.

It should be noted that the results expressed as a percentage, the declared values are within the date range of this network and may differ across conditions and other networks.

REFERENCES

1. Almas, M.S., et al., "Open source SCADA implementation and PMU integration for power system monitoring and control applications", in Proc. IEEE PES General Meeting, National Harbor, MD, US, July 2014.
2. Bhagwan Reddy, J., Reddy, D.N., "Probabilistic Performance Assessment of a Roof Top Wind, Solar Photo Voltaic Hybrid Energy System. Reliability and Maintainability", Annual Symposium–RAMS, PP: 654-658, 2004.
3. Birk, M., et al., "TSO/DSO coordination in a context of distributed energy resource penetration", Energy Economics Iberian Conference, Lisbon, Portugal, 2016.
4. de la Villa Jaén, A., et al., "Effect of the Conductor Temperature on the State Estimation of Power Systems", EEEJ, Vol.1, No.3.PP:19-24, 2016.
5. Duenas, P., "DSO-TSO coordination", Master's thesis, Escuela Tecnica Superior de Ingenieria.Universidad Pontificia Comillas, 2015.
6. Fabrizio, P., et al., "Control and automation functions at the TSO and DSO interface–impact on network planning", CIRED-Open Access Proceedings Journal, 1: 2188-2191, 2017.
7. Hadush, S. Y. and Meeus, L., "DSO-TSO cooperation issues and solutions for distribution grid congestion management", Energy Policy, 120: 610–621, 2018.
8. Hauer, A., et al., "Communication Interface Requirements during Critical Situations in a Smart Grid", IEEE. 14-17 Oct. Berlin, Germany.p.7, 2012.
9. MELO, F., et al. "Network active management for load balancing based in an intelligent multi-agent system", CIRED Workshop - Lisbon 29-30, Paper 357, May 2012.
10. Mukund R. Patel "Wind and solar power systems: design, analysis, and operation", Taylor & Francis Group, LLC.PP.448, 2006.
11. Neuhoff, K., and Richstein. J., "TSO-DSO-PX Cooperation. Report on the key elements of debate from a workshop of the Future Power Market Platform", Deutsches Institut für Wirtschaftsforschung (DIW), Berlin.PP.7, 2017.
12. Rui A., et al., "TSOs and DSOs Collaboration: The Need for Data Exchange", Engineering and Industry Series, 55-62, 2015.
13. SILVA, J., et al., "The challenges of estimating the impact of distributed energy resources flexibility on the TSO/DSO boundary node operating points", Computers & Operations Research, 96: 294-304,2018.
14. TRAN, J. et al., "Economic Optimization of Electricity Supply Security in Light of the Interplay between TSO and DSO", Energy Economics and Management, 2016.
15. YUAN, Z. and HESAMZADEH, M. R., "Hierarchical coordination of TSO-DSO economic dispatch considering large-scale integration of distributed energy resources", Applied Energy, 195: 600-615, 2017.
16. Zipf, M., and Most, D., "Cooperation of TSO and DSO to provide ancillary services", IEEE.PP.978, 2016.