Time-horizons in the planning and operation of transmission networks
An overview

Khuntia, Swasti R.; Tuinema, Bart W.; Rueda, José L.; van der Meijden, Mart A.M.M.

DOI
10.1049/iet-gtd.2015.0791

Publication date
2016

Document Version
Accepted author manuscript

Published in
IET Generation, Transmission and Distribution

Citation (APA)
Khuntia, S. R., Tuinema, B. W., Rueda, J. L., & van der Meijden, M. A. M. M. (2016). Time-horizons in the planning and operation of transmission networks: An overview. *IET Generation, Transmission and Distribution*, *10*(4), 841-848. https://doi.org/10.1049/iet-gtd.2015.0791

IET Generation, Transmission & Distribution

Review Article

Time-horizons in the planning and operation of transmission networks: an overview

ISSN 1751-8687
Received on 29th June 2015
Revised on 1st October 2015
Accepted on 30th October 2015
doi: 10.1049/iet-gtd.2015.0791
www.ietdl.org

Swasti R. Khuntia[1] ✉, Bart W. Tuinema[1], José L. Rueda[1], Mart A.M.M. van der Meijden[1,2]

[1]Department of Electrical Sustainable Energy, Delft University of Technology, Delft, The Netherlands
[2]TenneT TSO B.V., Arnhem, The Netherlands
✉ *E-mail: skhuntia@iit.edu*

Abstract: In the planning and operation of power systems, actions are taken in different processes and time-horizons. The purpose of these actions is to secure a high reliability level. Although the three main processes (grid development, asset management, and system operation) are described in literature, there has been no explicit study on the time-horizons (long-term, mid-term, and short-term) and actual time-scale (decades, years, months, etc.) that these processes focus on. This study aims at making a review of the various activities performed by transmission system operators while reviewing the concept of each time-horizon and methodologies developed in literature. As decisions taken in different time-horizons can influence each other, the interactions and overlapping are discussed.

1 Introduction

Today's scenario places tremendous stress on transmission and distribution (T&D) assets because of:

- Development and increase in electricity demand.
- Structural changes [more interconnections, intermittent renewable energy sources (RES), flexible AC transmission systems (FACTS), high voltage direct current (HVDC), and other power electronics-based devices].
- New operating policies like liberalisation of the energy market, more intense trading, coupled markets, higher demand-side participation.

This has led the power system reliability specialists to divide their activities into three main processes in which sets of decisions are taken. These activities are usually divided into the processes [1]:

(i) Grid development (long-term).
(ii) Asset management (AM) (mid-term).
(iii) System operation (short-term).

However, in reality under each of these three main processes, various sub-activities are performed on different time-horizons as illustrated in Fig. 1. The actual time scale of these horizons can vary between different processes and has never been clearly mentioned in any published literature, which can lead to confusion in practice. For example, long-term grid development is performed on a time scale of decades, while long-term system operation has a time scale of weeks/months as shown in Fig. 2. It is the primary scope of this paper to clarify this by bringing together the concept of different time-horizons in one survey, while embedding the various literatures as support. Furthermore, recent developments in the different time-horizons are discussed, as well as the overlapping between activities.

Discussion on planning and operation brings 'reliability' into picture. Power system reliability has been a subject of interest since the 1960s when Billinton and Bollinger [2] published the first article in 1968. Since then, there has been a huge amount of research introducing various methods and theory to pursue reliable power system operation. Besides, Billinton and other authors have made significant bibliographic studies about the probabilistic models in different periods. Some of these are Schilling *et al.* for the period 1962–1988 in 1990 [3], Billinton in 1972 [4], Allan *et al.* for 1987–1991 in 1994 [5], and Billinton *et al.* for 1996–1999 in 2001 [6]. Schilling *et al.* [7] made a comprehensive bibliographic study of probabilistic security analysis for the period 1968–2008 which included 521 articles in a 40-year range. In the past three decades, a variety of achievements have been accomplished on the concepts, models, algorithms, software and applications of power system reliability [8–10]. Reneses *et al.* [11], for the first time, discussed the importance of coordination among the time-horizons, stating how long-term decisions impact short-term decisions.

This paper is organised as follows. Section 2 focuses on the concept of different time-horizons, and lists the different methodologies developed in various literatures. Section 3 discusses the overlapping and interactions among the time-horizons, the possibilities for a combined reliability approach, and the challenges for the future. This section also concludes the literature survey.

2 Review of three main processes

In this section, the three main processes and time-horizons are discussed. Fig. 2 was created to understand the concept of three processes and horizons. It gives an overview of the activities that are performed in each process and time-horizon, and shows the actual time scale of these activities. The next sub-sections describe each of the processes in detail, supported by methods and tools published in various literatures.

2.1 Grid development

Grid development aims mainly at transmission system expansion planning. According to Pereira *et al.* [12], grid development can be divided into two parts:

- Determining optimal investments in new system capacity.
- Determining system operating cost and supply reliability associated with the construction of this new capacity.

In short, developing the transmission infrastructure is one of the key priorities. An adequate transmission network is responsible for a safe, reliable, and efficient delivery of electrical energy to the

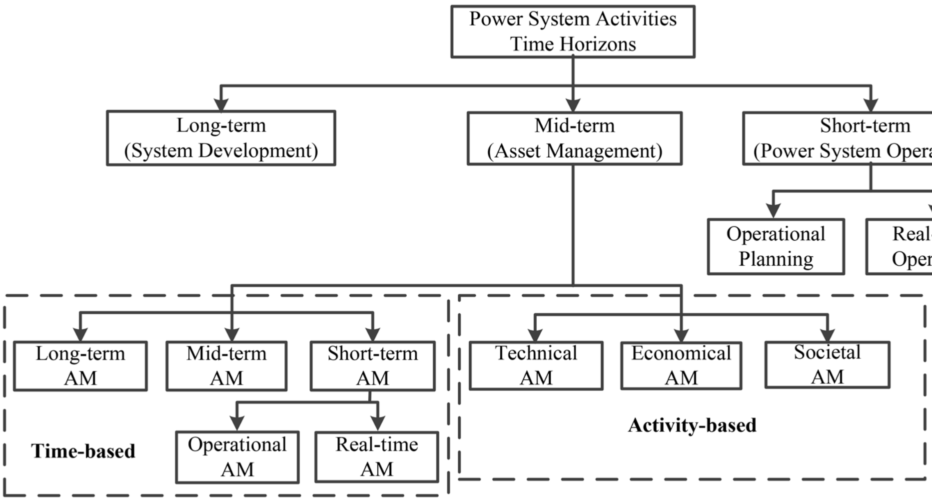


Fig. 1 *Classification of time-horizons according to literature*

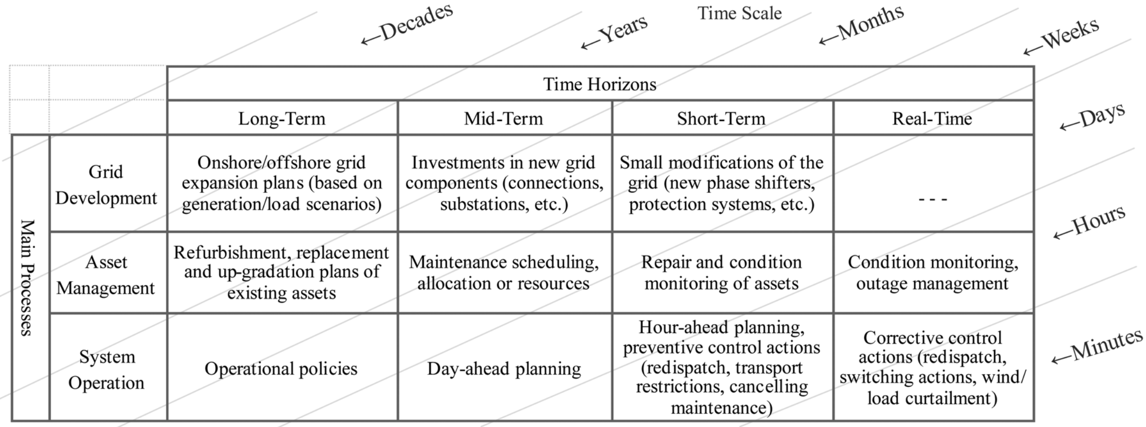
consumers. Thus, grid development aims at providing solutions for future. For an efficient planning, it is important to find the type, location, and timing of the network upgrades not only at a minimal cost but also considering socio-economic, environmental, reliability, legal, and political constraints. Since the fact that it generally covers the far future, grid development deals with a large number of uncertainties in various domains.

In practice, grid development is performed on longer and shorter time-horizons. *Long-term grid development* has a time scale of decades and includes the creation of grid expansion plans based on load/generation scenarios. In *mid-term grid development*, investments in the grid infrastructure (new connections, substations, etc.) are made. In *short-term grid development*, only small modifications of the network are made in the time scale of months. New protection systems, phase shifters, and so on can be installed in this time-horizon.

Literature survey, in the last four decades, reveals that transmission system expansion planning has evolved due to introduction of various mathematical models and techniques. In the recent period, Lattore *et al.* [13] in 2003, Lee *et al.* [14] in 2006, and Hemmati *et al.* [15, 16] in 2013 presented an extensive list of different models and tools used in transmission expansion planning. Thereafter, there has been no explicit study on this topic though Kishore and Singhal [17] did a review of transmission line planning in 2014. Basically, in grid development, stochastic studies have so far indicated very helpful in various studies [18–24]. Hobbs [25], in 1994, enlisted the use of optimisation methods to tackle planning horizon in electric utility. It can be deduced that mathematical modelling for grid development is a challenging task because of the presence of so many constraints and a high level of uncertainty.

In the last three decades, there have been ample amount of work done in this context. A brief study about the techniques, algorithms, and concepts already developed are (*though a many could not be cited due to the scope of this paper*) as follows: maximum principle [26], mixed-integer programming [27–31], linear and dynamic programming [12, 32–34], disjunctive mixed integer programming [35], branch and bound algorithm [36], implicit enumeration [37, 38], Benders decomposition [12, 39, 40], maximum flow [12], hierarchical decomposition [41], sensitivity analysis [42, 43], genetic algorithm (GA) [44–49], object-oriented programming [50], game-theory [51–54], simulated annealing [55, 56], expert systems [57, 58], fuzzy set [49, 59, 60], greedy randomised adaptive search [61], non-convex optimisation [62], tabu search [63], ant-colony [64], data-mining [65], particle swarm optimisation (PSO) [66–69], harmony search [70, 71], artificial neural network (ANN) [72], game theory [73], and robust optimisation techniques [74–78].

In addition to the various tools and methods, there is an immense requirement of tools and knowledge-based schemes for decision making to integrate RES under market regulations and uncertainties [79, 80]. This is a challenging task because of stochastic behaviour, non-linearities, and non-convexities [62] of RES. At the same time, the electricity market also adds to the uncertainty [81]. It can be deduced that risk and uncertainties have evolved due to advancement in technology, and will be evolving



Main Processes	Time Horizons: Long-Term	Mid-Term	Short-Term	Real-Time
Grid Development	Onshore/offshore grid expansion plans (based on generation/load scenarios)	Investments in new grid components (connections, substations, etc.)	Small modifications of the grid (new phase shifters, protection systems, etc.)	- - -
Asset Management	Refurbishment, replacement and up-gradation plans of existing assets	Maintenance scheduling, allocation or resources	Repair and condition monitoring of assets	Condition monitoring, outage management
System Operation	Operational policies	Day-ahead planning	Hour-ahead planning, preventive control actions (redispatch, transport restrictions, cancelling maintenance)	Corrective control actions (redispatch, switching actions, wind/ load curtailment)

Fig. 2 *Actions taken during different time-horizons*

further. For instance, some of the novel emerging/prominent approaches for expansion planning are based on least-effort criterion [82], maximum principle [26], minimising the maximum regret or maximising benefits [83], uncertainties [84], and security constraints [85]. Moreover, there are also environmental concerns when RES are considered. Correa *et al.* [86] did a comprehensive study of the impact of transmission expansion planning on environmental conditions. To cite an example, external factors like emission constraints [87, 88], efficiency measures, pollution control, and other environmental policy greatly influence grid development.

2.2 Asset management

Asset management, termed as mid-term horizon, is defined as the process of maximising the return on investment of equipment over its entire life cycle by maximising performance and minimising costs (both capital expenditure and operational expenditure) at a given risk level [89]. In the power industry, T&D components are capital-intensive assets and there is a requirement of utilising them in the most efficient way. Since the late 1990s, the power industry has been substantially deregulated, which gave birth to 'asset management'.

AM is closely related to grid development and system operation, hence forms a bridge between the long-term and short-term horizons. CIGRE WG D1.17 [90] shows how AM relies on asset data and information extracted from this data that is used in future planning. Accurate, timely, and reliable asset information results in better decisions and in the past, there has been much research on various aspects of AM [91–94].

As seen in Fig. 1, AM can be classified based on time domain and activity domain. The time-domain AM is categorised into long-, mid-, and short-term:

- *Long-term AM:* The time frame ranges from a year and beyond and it aims at replacement, refurbishment or up-gradation of existing assets like phase-shifting transformers, reactive devices, and existing connections. This involves greater financial risks, and hence proper planning can avoid the risks involved in time delays, interest rates, and long-term load diversity.
- *Mid-term AM:* The time frame ranges a few months and it mainly involves optimal scheduling of equipment maintenance to extend the life span of existing facilities and to prevent unplanned outages. Maintenance costs are the driving factor since it is a function of outages (both planned and unplanned), and can be greatly reduced when planned outages are scheduled according to the availability of resources during seasonal load distributions.
- *Short-term AM:* Short-term AM is categorised into operational AM (daily/weekly) and real-time AM. Operational AM aims at minimising risks involved with assets, both physical and financial, due to load demand. Real-time AM is also called asset outage management. Contingency analysis forms a vital part. It helps in assessing the effect of unexpected outages due to changes in weather conditions, any sudden breakdown or load fluctuations on the asset condition and performance. In recent times, due to technological advancements, real-time monitoring of assets is possible.

On the basis of activity aspect, Smit *et al.* [93] categorise AM into technical-, economical-, and societal-AM. Technical AM deals with ageing, insulation, and other physical conditions of assets. Socio-economic aspect is broken down to individual aspects, which deal with how AM would be influenced by financial constraints and eventually its impact on society.

As seen from the above classification, maintenance forms the crucial part of AM. Literature survey shows there have been explicit studies on maintenance of various power system components, like power transformers, overhead lines, cables, and protection devices [95–103]. With the integration of RES, wind farms have been extensively studied from AM point of view in [96, 97, 104–107]. Suwanasri *et al.* [108] studied a zero-profit method for up-gradation of high-voltage equipment in a substation, i.e. power transformers, current transformers, voltage transformers, high-voltage circuit breakers, switches, and surge arresters. In general, the power transformer represents ~60% of the overall costs of the network, and is ranked as one of the most important and expensive components [109]. Study reveals about substantial research on power transformers in various literature about health monitoring, ageing, and oil indicators [110–115]. Similarly, studies have been carried out for overhead lines [115–118], underground cables [115, 119, 120], and circuit breakers [115, 121–124]. Yoon and Teo [125] presented a real-life case study on AM in Singapore though it focused on underground grids. With the advent of computational tools, information technology (IT), and human–machine interface in the last decade, Kostic [126, 127] made studies on the application of IT in AM while focusing on energy management services.

Various computational models and optimisation techniques have been developed for maintenance, refurbishment, ageing, and monitoring techniques in AM, like state diagram [128], fuzzy technique [105, 113, 129], ANN [109], PSO [106], linear programming [118, 130], branch and bound technique [131], and other optimisation techniques [132, 133].

2.3 System operation

System operation encompasses real-time operation and operational planning, which deals with activities ahead of real time. The duration of this time-horizon ranges from minutes/hours to several days ahead, though this can vary between different transmission system operators. Reliability is of primary concern and it is very important to maintain both security and adequacy levels at the acceptable levels with minimum socio-economic cost. System security level refers to the ability of the system to response to failures [8, 10]. This ensures that the dynamics induced from any contingency or any operating conditions remain within acceptable level. System adequacy indicates whether there are enough means in the system to fulfil its function, also during contingencies. A detailed analysis of the two sub-levels is performed:

- *Operational planning:* Operational planning happens at several instances prior to the establishment of the system operating conditions. It constitutes the preparatory phases before real-time operation. Also, operational planning ensures that right decisions are taken in advance such that reliability management is achievable within a prolonged future period of time, called the operational planning horizon. The horizon consists of a sequence of target real-time intervals. The operational planning time-horizon does not have a specific point in time, it can be week-ahead (W-1), two days (D-2) or one day (D-1) in advance as well as several (*n*) hours (H-*n*) before real time. Due to the unspecific points in time, operational planning brings few uncertainties into consideration.
- *Real-time operation:* Real-time operation encompasses system operation for time intervals ranging 15–60 min. During this time interval, it is assumed that the system operating conditions (scheduled generation, demand, inter-area exchange, and network configuration) are highly predictable. Fig. 3 shows the inter-dependency of real-time operation and operational planning. Real-time operation is a series of activities, which are planned in a sequential manner. It starts with the preventive control, with a horizon of 1–2 h, and aims operation at optimal cost under security constraints. Preventive action is always planned and covers failures or unexpected reactions from the system point of view. Taking preventive decisions such as switching equipment, rescheduling loads, is also part of the sequence. Furthermore, it oversees contingencies, and prepares or adjusts the system to take control decisions. Preventive control may be followed by two other control strategies, namely corrective control and emergency control. Corrective control is the first step taken following preventive control. The horizon is 0–15 min, and aims at maintaining the system intact. Emergency action is the control

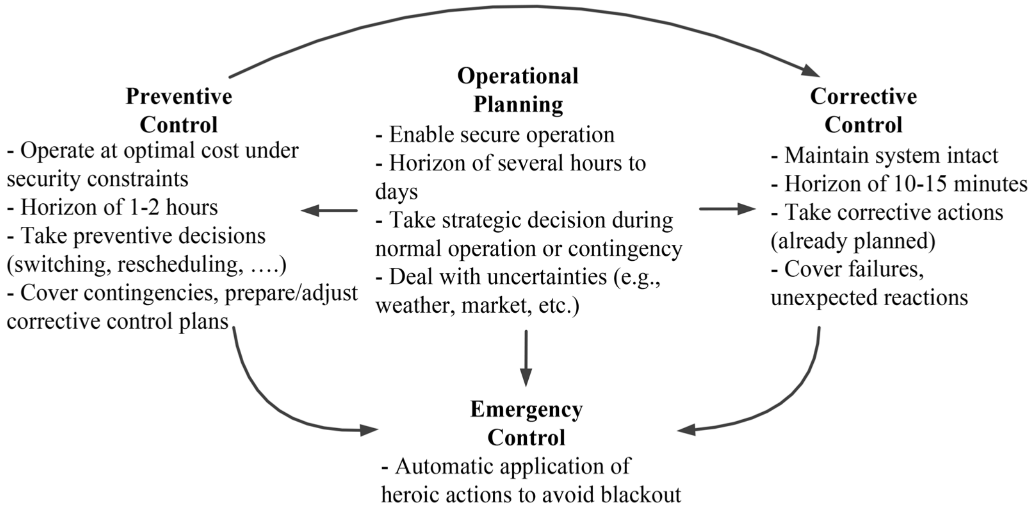


Fig. 3 *Actions taken during short-term operational planning*

scheme of real-time operation. Both preventive as well as corrective action may end up in emergency action in the worst-case scenario. Emergency action is taken during any unplanned contingency or failure when the effect of a contingency is not sufficiently covered by means of preventive and corrective actions.

Literature study reveals comprehensive methodologies for preventive and corrective actions. Load shedding, considered as corrective action, is verified in various literatures [134–138]. Other various mathematical modelling and optimisation techniques include: PSO [139], decision trees [140–145], model predictive control [146], ant colony system [147–149], GA and ANN [150], differential evolution [151, 152], and various other optimisation techniques [153, 154].

In system operation, decisions are taken within a limited time. Probabilistic risk analysis is already often used in grid development, but the application in system operation is relatively new. IEEE and CIGRE have developed task forces working on risk analysis and probabilistic techniques for planning and operation [155, 156]. Recently, various domains in risk-based planning have been studied, like power transfer limit [157], weather conditions [158], stability [159], and reserve generation [160]. Preece and Milanovic [159] combined probabilistic and fuzzy inference systems to categorise different degrees of risk, which facilitates the understanding of the planner. The paper focuses on stability issues and the methodology was applied to a multi-area network, but the concept can also be applied to reliability problems. Ciapessoni *et al.* [161] studied the advantages of integrating probabilistic and deterministic tools for enhancing security during short-term horizon.

3 Conclusions

This paper reviewed the concept of different main processes and time-horizons in the planning and operation of power systems. The authors have tried their best to encompass adequate theory with supporting literature for the different time-horizons. Not only in terms of time scale but also the tasks involved in each of the time-horizons make them different from each other. In some cases, short-term planning may work out efficiently, but it may not be adequate in identifying the long term needs of the system. For example, in the short term, a lower voltage and less expensive line addition may be adequate but may require an expensive upgrade within a decade. In contrast, an initially more expensive and higher capacity line might be less expensive in the long term.

There is always an overlap among the different processes, as illustrated in Fig. 4. Without discussing this overlap, the work

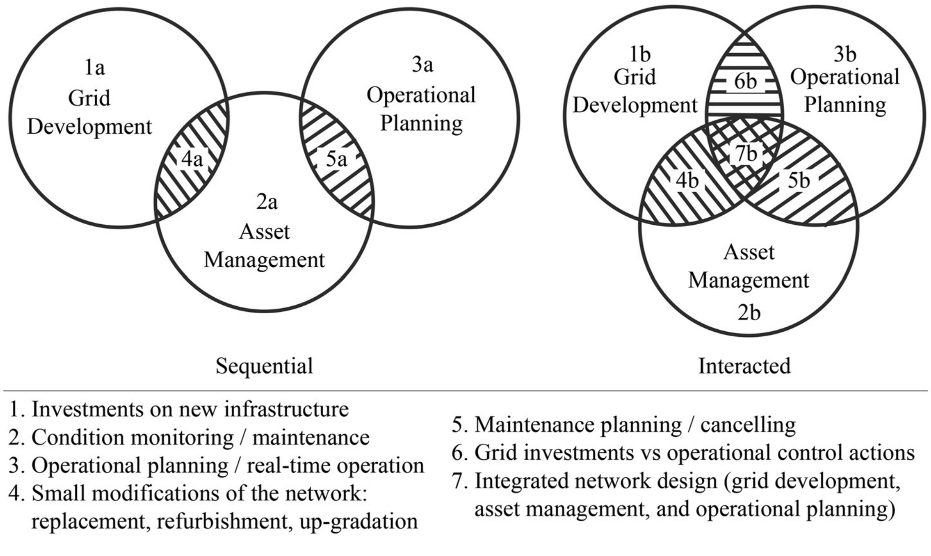


Fig. 4 *Interactions among the three processes*

Table 1 Future (possible) challenges due to interaction of different time-horizons

Challenge	Description
uncertainty modelling	modelling the variability of RES, market uncertainties, variable demand, high-impact-low-probability events, operating conditions, contingency modelling
data management	handling large amounts of data, collecting suitable failure statistics of network components
tools	develop complex methods in academia for easy understanding and use in the real life. Risk analysis of large-scale systems with large amount of uncertainties within a reasonable computing time
result interpretation	presentation of the results of probabilistic reliability analysis in clear, understandable and actionable indices

would be incomplete. Small modifications of the network can be required because of grid development or because of AM (area-4a in Fig. 4) and planned maintenance might be cancelled during system operation because of a contingency (area-5a). In the past, the three processes consisted of more or less separate activities. This is illustrated as a sequential approach in Fig. 4. For example, the Dutch 380 kV ring was developed considering $n-2$ ($n-1$ during maintenance) redundancy (area-1a). As a result, this gave enough room to plan maintenance in AM (area-2a), and enough room for operational activities (area-3a). In the future, the overlap and interaction between the three main processes is expected to increase, because of the developments as mentioned initially in this work (also refer Fig. 4 for interacted approach). Earlier studies showed that offshore network redundancy is mostly uneconomical [162]. Onshore spinning generation reserve can serve as redundancy for the offshore network to maintain a high level of reliability of supply (area-6b in Fig. 4). If redundancy is not created in the offshore network (long-term activity), this has consequences for activities in other time-horizons.

Several (possible) challenges can be expected for future as enlisted in Table 1. Uncertainty modelling is one of the primary challenges followed by big data. The management of large amount of data poses a second challenge. Furthermore, the development of new risk tools and clear interpretation of results are of importance, as risk analysis is useless if the results cannot be translated into actions. Various projects on pan-European electric power system are working towards improving reliability or developing a new reliability criterion. Vefsnmo *et al.* [163] in AFTER project (http://www.after-project.eu) are developing risk assessment tool to be used in short-term horizon. GARPUR project (http://www.garpur-project.eu) aims at developing new reliability criteria taking into consideration the three time-horizons (http://www.garpur-project.eu/deliverables). As transmission system planners face numerous challenges originated in load growth, economic forces of deregulation, and development and integration of new technologies, this paper presents recent literatures to keep up with the advancement.

In the end, the authors would like to state that large number of articles could not be cited in this paper since citing all would be out of scope of this paper. For a clear picture of recent developments, a table of publication listing in the last four decades is shown in Table 2. From the table, it can be noted that the work has focused on literatures published in the last 10 years, thus presenting the recent state-of-art methodologies.

Table 2 Publication listing

Time frame	Number of publications
2006–2015 (present)	103
1996–2005	40
before–1995	20

4 Acknowledgment

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement no. 608540 GARPUR project http://www.garpur-project.eu.

5 References

1 Wood, A.J., Wollenberg, B.F.: 'Power generation, operation, and control' (John Wiley & Sons, 2012)
2 Billinton, R., Bollinger, K.E.: 'Transmission system reliability evaluation using Markov processes', *IEEE Trans. Power Appar. Syst.*, 1968, **87**, (2), pp. 538–547
3 Schilling, M.T., Leite da, Silva A.M., Billinton, R., *et al.*: 'Bibliography on power system probabilistic analysis (1962–88)', *IEEE Trans. Power Syst.*, 1990, **5**, (1), pp. 1–11
4 Schilling, M.T., Leite da Silva, A.M., Billinton, R., *et al.*: 'Bibliography on the application of probability methods in power system reliability evaluation', *IEEE Trans. Power Appar. Syst.*, 1972, **91**, (2), pp. 649–660
5 Allan, R.N., Billinton, R., Breipohl, A.M., *et al.*: 'Bibliography on the application of probability methods in power system reliability evaluation: 1987–1991', *IEEE Trans. Power Syst.*, 1994, **9**, (1), pp. 41–49
6 Billinton, R., Fotuhi-Firuzabad, M., Bertling, L.: 'Bibliography on the application of probability methods in power system reliability evaluation 1996–1999', *IEEE Trans. Power Syst.*, 2001, **16**, (4), pp. 595–602
7 Schilling, M.T., Billinton, R., Groetaers dos Santos, M.: 'Bibliography on power systems probabilistic security analysis 1968–2008', *Emerging Electr. Power Syst.*, 2009, **10**, (3), pp. 1–48
8 Billinton, R., Allan, R.N.: 'Reliability evaluation of power systems' (Plenum Press, New York, 1996)
9 Guo, Y.: 'Power system reliability analysis' (Tsinghua Press, Beijing, 2003)
10 Billinton, R., Li, W.: 'Reliability assessment of electric power systems using Monte Carlo methods' (Plenum Press, New York, 1994)
11 Reneses, J., Centeno, E., Barquin, J.: 'Coordination between medium-term generation planning and short-term operation in electricity markets', *IEEE Trans. Power Syst.*, 2006, **21**, (1), pp. 43–52
12 Pereira, M.V.F., Pinto, L.M.V.G., Cunha, S.H.F., *et al.*: 'A decomposition approach to automated generation/transmission expansion planning', *IEEE Trans. Power Appar. Syst.*, 1985, **104**, (11), pp. 3074–3083
13 Latorre, G., Cruz, R.D., Areiza, J.M., *et al.*: 'Classification of publications and models on transmission expansion planning', *IEEE Trans. Power Syst.*, 2003, **18**, (2), pp. 938–946
14 Lee, C.W., Ng, S.K.K., Zhong, J., *et al.*: 'Transmission expansion planning from past to future'. Proc. of IEEE Power Systems Conf. Exposition, 2006
15 Hemmati, R., Hooshmand, R.-A., Khodabakhshian, A.: 'State-of-the-art of transmission expansion planning: comprehensive review', *Renew. Sustain. Energy Rev.*, 2013, **23**, pp. 312–319
16 Hemmati, R., Hooshmand, R.-A., Khodabakhshian, A.: 'Comprehensive review of generation and transmission expansion planning', *IET Gener. Transm. Distrib.*, 2013, **7**, (9), pp. 955–964
17 Kishore, T.S., Singal, S.K.: 'Optimal economic planning of power transmission lines: a review', *Renew. Sustain. Energy Rev.*, 2014, **39**, pp. 949–974
18 Gu, Y.: 'Long-term power system capacity expansion planning considering reliability and economic criteria' (Iowa State University, 2011)
19 Genesi, C., Marannino, P., Montagna, M., *et al.*: 'Risk management in long term generation planning'. Proc. of European Energy Market Conf., 2009
20 Barquin, J., Centeno, E., Reneses, J.: 'Stochastic market equilibrium model for generation planning'. Proc. of IEEE Probabilistic Methods Applied to Power Systems Conf., 2004
21 Papaefthymiou, G., Schavemaker, P.H., van der Sluis L., *et al.*: 'Integration of stochastic generation in power systems', *Electr. Power Energy Syst.*, 2006, **28**, (9), pp. 655–667
22 Papaefthymiou, G., Kurowicka, D.: 'Using copulas for modeling stochastic dependence in power system uncertainty analysis', *IEEE Trans. Power Syst.*, 2009, **24**, (1), pp. 40–49
23 De la Torre, S., Conejo, A.J., Contreras, J.: 'Transmission expansion planning in electricity markets', *IEEE Trans. Power Syst.*, 2008, **23**, (1), pp. 238–248
24 Villumsen, J.C., Philpott, A.B.: 'Investment in electricity networks with transmission switching', *Eur. J. Oper. Res.*, 2012, **222**, (2), pp. 377–385
25 Hobbs, B.F.: 'Optimization methods for electric utility resource planning', *Eur. J. Oper. Res.*, 1995, **83**, (1), pp. 1–20
26 Kim, K.J., Park, Y.M., Lee, K.Y.: 'Optimal long term transmission expansion planning based on maximum principle', *IEEE Trans. Power Syst.*, 1988, **3**, (4), pp. 1494–1501
27 Alguacil, N., Motto, A.L., Conejo, A.J.: 'Transmission expansion planning: a mixed-integer LP approach', *IEEE Trans. Power Syst.*, 2003, **18**, (3), pp. 1070–1077
28 Zhang, H., Vittal, V., Heydt, G.T., *et al.*: 'A mixed-integer linear programming approach for multi-stage security-constrained transmission expansion planning', *IEEE Trans. Power Syst.*, 2012, **27**, (2), pp. 1125–1133
29 Pozo, D., Sauma, E.E., Contreras, J.: 'A three-level static MILP model for generation and transmission expansion planning', *IEEE Trans. Power Syst.*, 2013, **28**, (1), pp. 202–210
30 Alizadeh, B., Jadid, S.: 'Reliability constrained coordination of generation and transmission expansion planning in power systems using mixed integer programming', *IET Gener. Transm. Distrib.*, 2011, **5**, (9), pp. 948–960

31 Aguado, J.A., de la Torre, S., Contreras, J., *et al.*: 'Market-driven dynamic transmission expansion planning', *Electr. Power Syst. Rese.*, 2012, **82**, (1), pp. 88–94

32 Garver, L.L.: 'Transmission network estimation using linear programming', *IEEE Trans. Power Appar. Syst.*, 1970, **89**, (7), pp. 1688–1697

33 Kaltenbatch, J.C., Peshon, J., Gehrig, E.H.: 'A mathematical optimization technique for the expansion of electrical power transmission systems', *IEEE Trans. Power Appar. Syst.*, 1970, **89**, (1), pp. 113–119

34 Leou, R.-C.: 'A multi-year transmission planning under a deregulated market', *Electr. Power Energy Syst.*, 2011, **33**, (3), pp. 708–714

35 Bahiense, L., Oliveira, G.C., Pereira, M., *et al.*: 'A mixed integer disjunctive model for transmission network expansion', *IEEE Trans. Power Syst.*, 2001, **16**, pp. 560–565

36 Haffner, S., Monticelli, A., Garcia, A., *et al.*: 'Branch and bound algorithm for transmission system expansion planning using a transportation model', *Proc. IEE Gener. Transm. Distrib.*, 2000, **147**, (3), pp. 149–156

37 Santos, A. Jr., França, P.M., Said, A.: 'An optimization model for long range transmission expansion planning', *IEEE Trans. Power Syst.*, 1989, **4**, (1), pp. 94–101

38 Romero, R., Monticelli, A.: 'A zero-one implicit enumeration method for optimizing investment in transmission expansion planning', *IEEE Trans. Power Syst.*, 1994, **9**, (3), pp. 1385–1391

39 Binato, S., Pereira, M.V.F., Granville, S.: 'A new Benders decomposition approach to solve power transmission network design problems', *IEEE Trans. Power Syst.*, 2001, **16**, (2), pp. 235–240

40 Asadamongkol, S., Eua-arporn, B.: 'Transmission expansion planning with AC model based on generalized Benders decomposition', *Electr. Power Energy Syst.*, 2013, **47**, pp. 402–407

41 Romero, R., Monticelli, A.: 'A hierarchical decomposition approach for transmission network expansion planning', *IEEE Trans. Power Syst.*, 1994, **9**, (1), pp. 373–380

42 Pereira, M.V.F., Pinto, L.M.V.: 'Application of sensitivity analysis of load supplying capability to interactive transmission expansion planning', *IEEE Trans. Power Appar. Syst.*, 1985, **104**, (2), pp. 381–389

43 Ekwue, A.O.: 'Investigations of the transmission systems expansion problem', *Electr. Power Energy Syst.*, 1984, **6**, pp. 139–142

44 da Silva, E.L., Gil, H.A., Areiza, J.M.: 'Transmission network expansion planning under an improved genetic algorithm', *IEEE Trans. Power Syst.*, 2000, **15**, (3), pp. 1168–1175

45 Yoshimoto, K., Yasuda, K., Yokohama, R.: 'Transmission expansion planning using neuro-computing hybridized with genetic algorithm'. Proc. of IEEE Int. Conf. on Evolutionary Computation, 1995

46 Gallego, R.A., Monticelli, A., Romero, R.: 'Transmission expansion planning by extended genetic algorithm', *Proc. IEE Gener. Transm. Distrib.*, 1998, **145**, (3), pp. 329–335

47 Maghouli, P., Hosseini, S.H., Buygi, M.O., *et al.*: 'A scenario-based multi-objective model for multi-stage transmission expansion planning', *IEEE Trans. Power Syst.*, 2011, **26**, (1), pp. 470–478

48 Cadini, F., Zio, E., Petrescu, C.A.: 'Optimal expansion of an existing electrical power transmission network by multi-objective genetic algorithms', *Reliab. Eng. Syst. Saf.*, 2010, **95**, (3), pp. 173–181

49 Foroud, A.A., Abdoos, A.A., Keypour, R., *et al.*: 'A multi-objective framework for dynamic transmission expansion planning in competitive electricity market', *Electr. Power Energy Syst.*, 2010, **32**, (8), pp. 861–872

50 Handschin, E., Heine, M., König, D., *et al.*: 'Object-oriented software engineering for transmission planning in open access schemes', *IEEE Trans. Power Syst.*, 1998, **13**, (1), pp. 94–100

51 Contreras, J., Wu, F.F.: 'A kernel-oriented algorithm for transmission expansion planning', *IEEE Trans. Power Syst.*, 2000, **15**, (1), pp. 1434–1440

52 Contreras, J., Wu, F.F.: 'Coalition formation in transmission expansion planning', *IEEE Trans. Power Syst.*, 1999, **14**, (3), pp. 1144–1152

53 Jenabi, M., Fatemi Ghomi, S.M.T., Smeers, Y.: 'Bi-level game approaches for coordination of generation and transmission expansion planning within a market environment', *IEEE Trans. Power Syst.*, 2013, **28**, (3), pp. 2639–2650

54 Li, X., Li, Y., Zhu, X., *et al.*: 'Generation and transmission expansion planning based on game theory in power engineering', *Syst. Eng. Proc.*, 2012, **4**, pp. 79–86

55 Gallego, R.A., Alves, A.B., Monticelli, A., *et al.*: 'Parallel simulated annealing applied to long term transmission network expansion planning', *IEEE Trans. Power Syst.*, 1997, **12**, (1), pp. 181–188

56 Romero, R., Gallego, R.A., Monticelli, A.: 'Transmission system expansion planning by simulated annealing', *IEEE Trans. Power Syst.*, 1996, **11**, (1), pp. 364–369

57 Teive, R.C.G., Silva, E.L., Fonseca, L.G.S.: 'A cooperative expert system for transmission expansion planning of electrical power systems', *IEEE Trans. Power Syst.*, 1998, **13**, (2), pp. 636–642

58 Teive, R.C.G., Fonseca, L.G.S.: 'A hybrid system based on knowledge to the electrical power networks expansion planning'. Proc. of IEEE PowerTech Conf., 1995

59 Sun, H., Yu, D.C.: 'A multiple-objective optimization model of transmission enhancement planning for independent transmission company (ITC)'. Proc. of IEEE Power Engineering Society Summer Meeting, 2000

60 Sousa, A.S., Asada, E.N.: 'Combined heuristic with fuzzy system to transmission system expansion planning', *Electr. Power Syst. Res.*, 2011, **81**, (1), pp. 123–128

61 Binato, S., Oliveira, G.C., Araújo, J.L.: 'A greedy randomized adaptive search procedure for transmission expansion planning', *IEEE Trans. Power Syst.*, 2001, **16**, (2), pp. 247–253

62 Gallego, R.A., Monticelli, A., Romero, R.: 'Comparative studies on nonconvex optimization methods for transmission network expansion planning', *IEEE Trans. Power Syst.*, 1998, **13**, (3), pp. 822–828

63 da Silva, E.L., Areiza, J.M., de Oliveira, G.C., *et al.*: 'Transmission network expansion planning under a tabu search approach', *IEEE Trans. Power Syst.*, 2001, **16**, (1), pp. 62–68

64 Leite da Silva, A.M., Rezende, L.S., da Fonseca Manso, L.A., *et al.*: 'Reliability worth applied to transmission expansion planning based on ant colony system', *Electr. Power Energy Syst.*, 2010, **32**, (10), pp. 1077–1084

65 Ferreira, J., Ramos, S., Vale, Z., *et al.*: 'A data-mining-based methodology for transmission expansion planning', *IEEE Trans. Intell. Transp. Syst.*, 2011, **26**, (2), pp. 28–37

66 Torres, S.P., Castro, C.A.: 'Parallel particle swarm optimization applied to the static transmission expansion planning problem'. Proc. of IEEE Transmission and Distribution: Latin America Conf. Exposition, 2012

67 Eghbal, M., Saha, T.K., Hasan, K.N.: 'Transmission expansion planning by meta-heuristic techniques: a comparison of shuffled frog leaping algorithm, PSO and GA'. Proc. of IEEE Power and Energy Society General Meeting, 2011

68 Jin, Y.-X., Cheng, H.-Z., Yan, J., *et al.*: 'New discrete method for particle swarm optimization and its application in transmission network expansion planning', *Electr. Power Syst. Res.*, 2007, **77**, (3–4), pp. 227–233

69 Shayeghi, H., Mahdavi, M., Bagheri, A.: 'Discrete PSO algorithm based optimization of transmission lines loading in TNEP problem', *Energy Convers. Manage.*, 2010, **51**, (1), pp. 112–121

70 Verma, A., Panigrahi, B.K., Bijwe, P.R.: 'Harmony search algorithm for transmission network expansion planning', *IET Gener. Transm. Distrib.*, 2010, **4**, (6), pp. 663–673

71 Bertsch, V., Fichtner, W.: 'A participatory multi-criteria approach for power generation and transmission planning', *Ann. Oper. Res.*, 2015, pp. 1–31

72 Al-Saba, T., El-Amin, I.: 'The application of artificial intelligent tools to the transmission expansion problem', *Electr. Power Syst. Res.*, 2002, **62**, (2), pp. 117–126

73 Sauma, E.E., Oren, S.S.: 'Proactive planning and valuation of transmission investments in restructured electricity markets', *J. Regul. Econ.*, 2006, **30**, (3), pp. 261–290

74 Soyster, A.: 'Convex programming with set-inclusive constraints and applications to inexact linear programming', *Oper. Res.*, 1973, **21**, (5), pp. 1154–1157

75 Bertsimas, D., Brown, D.B., Caramanis, C.: 'Theory and applications of robust optimization', *SIAM Rev.*, 2011, **53**, (3), pp. 464–501

76 Jabr, R.A.: 'Robust transmission network expansion planning with uncertain renewable generation and loads', *IEEE Trans. Power Syst.*, 2013, **28**, (4), pp. 4558–4567

77 Ruiz, C., Conejo, A.J.: 'Robust transmission expansion planning', *Eur. J. Oper. Res.*, 2015, **242**, (2), pp. 390–401

78 Moreira, A., Street, A., Arroyo, J.M.: 'An adjustable robust optimization approach for contingency-constrained transmission expansion planning', *IEEE Trans. Power Syst.*, 2015, **30**, (4), pp. 2013–2022

79 Milligan, M., Donohoo, P., O'Malley, P.: 'Stochastic methods for planning and operating power system with large amounts of wind and solar power'. NREL/CP-5500-56208, Golden, CO, 2012

80 Ugranli, F., Karatepe, E.: 'Transmission expansion planning for wind turbine integrated power systems considering contingencies'. Proc. of IEEE Int. Symp. on Innovations in Intelligent Systems and Applications, 2014

81 Munoz, F.D., Hobbs, B.F., Ho, J.L., *et al.*: 'An engineering-economic approach to transmission planning under market and regulatory uncertainties: WECC case study', *IEEE Trans. Power Syst.*, 2014, **29**, (1), pp. 307–317

82 Monticelli, A., Santos, A., Pereira, M.V.F., *et al.*: 'Interactive transmission network planning using a least-effort criterion', *IEEE Trans. Power Appar. Syst.*, 1982, **PAS-101**, (10), pp. 3919–3925

83 De la Torre, T., Feltes, J.W., Gomez San Roman, T., *et al.*: 'Deregulation, privatization, and competition: transmission planning under uncertainty', *IEEE Trans. Power Syst.*, 1999, **14**, (2), pp. 460–465

84 Gorenstin, B.G., Campodonico, N.M., da Costa, J.P., *et al.*: 'Power system expansion planning under uncertainty', *IEEE Trans. Power Syst.*, 1993, **8**, (1), pp. 129–136

85 Kazerooni, K., Mutale, J.: 'Transmission network planning under security and environmental constraints', *IEEE Trans. Power Syst.*, 2010, **25**, (2), pp. 1169–1178

86 Correa, C.A., Bolanos, R., Garces, A., *et al.*: 'Multi objective environmental transmission network expansion planning'. Proc. of IEEE PowerTech Conf., 2013

87 Webster, M., Donohoo, P., Palmintier, B.: 'Water-CO_2 trade-offs in electricity generation planning', *Nat. Clim. Change*, 2013, **3**, (12), pp. 1029–1032

88 Careri, F., Genesi, C., Marannino, P., *et al.*: 'Generation expansion planning in the age of green economy', *IEEE Trans. Power Syst.*, 2011, **26**, (4), pp. 2214–2223

89 Tor, O., Shahidehpour, M.: 'Power distribution asset management'. Proc. of IEEE Power Engineering Society General Meeting, 2006

90 CIGRE WG D1.17: 'Generic guidelines for life time condition assessment of HV assets and related knowledge rules', 2010

91 Mehairjan, R.P.Y., Djairam, D., Zhuang, Q., *et al.*: 'Statistical life data analysis for electricity distribution cable assets – an asset management approach'. Proc. of IET and IAM Asset Management Conf., 2011

92 Mohapatra, S.K.R., Mukhopadhyay, S.: 'Risk and asset management of transmission system in a reformed power sector'. Proc. of IEEE Power India Conf., 2006

93 Smit, J.J., Quak, B., Gulski, E.: 'Integral decision support for asset management of electrical infrastructures'. Proc. of IEEE Systems, Man, and Cybernetics Conf., 2006

94 Endo, F., Kanamitsu, M., Shiomi, R., *et al.*: 'Optimization of asset management and power system operation based on equipment performance'. Proc. of IEEE Int. Conf. on Condition Monitoring and Diagnosis, 2008

95 Lindquist, T.M., Bertling, L., Eriksson, R.: 'Circuit breaker failure data and reliability modelling', *IET Gener. Transm. Distrib.*, 2008, **2**, (6), pp. 813–820

96 Puglia, G., Bangalore, P., Tjernberg, L.B.: ‘Cost efficient maintenance strategies for wind power systems using LCC’. Proc. of Int. Conf. on Probabilistic Methods Applied to Power Systems, 2014

97 Nilsson, J., Bertling, L.: ‘Maintenance management of wind power systems using condition monitoring systems – life cycle cost analysis for two case studies’, *IEEE Trans. Energy Convers.*, 2007, **22**, (1), pp. 223–229

98 Franzén, A., Bertling, L.: ‘State of the art-life time modeling and management of transformers’ (Royal Institute of Technology, Stockholm, 2007)

99 Kalinowski, B., Anders, G.: ‘A new look at component maintenance practices and their effect on customer, station and system reliability’, *Electr. Power Energy Syst.*, 2006, **28**, (10), pp. 679–695

100 Abu-Elanien, A.E.B., Salama, M.M.A.: ‘Asset management techniques for transformers’, *Electr. Power Syst. Res.*, 2010, **80**, (4), pp. 456–464

101 Velasquez-Contreras, J.L., Sanz-Bobi, M.A., Arellano, S.G.: ‘General asset management model in the context of an electric utility: application to power transformers’, *Electr. Power Syst. Res.*, 2011, **81**, (11), pp. 2015–2037

102 Heggset, J., Solvang, E., Christensen, J.S., *et al.*: ‘Failure models for network components as a basis for asset management’. Proc. of Nordic Distribution and Asset Management Conf., 2006

103 Brown, R.E., Spare, J.H.: ‘Asset management, risk, and distribution system planning’. Proc. of IEEE Power Systems Conf. on Exposition, 2004

104 Besnard, F., Fischer, K., Bertling, L.: ‘Reliability-centered asset maintenance – a step towards enhanced reliability, availability, and profitability of wind power plants’. Proc. of Innovative Smart Grid Technology Conf. Europe, 2010

105 Dehghanian, P., Fotuhi-Firuzabad, M., Bagheri-Shouraki, S., *et al.*: ‘Critical component identification in reliability centered asset management of power distribution systems via fuzzy AHP’, *IEEE Syst. J.*, 2012, **6**, (4), pp. 593–602

106 Heo, J.-H., Lyu, J.-K., Kim, M.-K., *et al.*: ‘Application of particle swarm optimization to the reliability centered maintenance method for transmission systems’, *Electr. Eng. Technol.*, 2012, 7, (6), pp. 814–823

107 Byon, E., Ntaimo, L., Ding, Y.: ‘Optimal maintenance strategies for wind turbine systems under stochastic weather conditions’, *IEEE Trans. Reliab.*, 2010, **59**, (2), pp. 393–404

108 Suwanasri, C., Suwanasri, T., Wattanawongpitak, S.: ‘A new asset value estimation using zero profit method for renovation planning of high voltage equipment in power substation’, *Int. Trans. Electr. Energy Syst.*, 2014, **24**, (12), pp. 1633–1649

109 Jahromi, A., Piercy, R., Cress, S., *et al.*: ‘An approach to power transformer asset management using health index’, *IEEE Electr. Insul. Mag.*, 2009, **25**, (2), pp. 20–34

110 Zhang, X., Gockenbach, E.: ‘Asset-management of transformers based on condition monitoring and standard diagnosis’, *IEEE Electr. Insul. Mag.*, 2008, **24**, (4), pp. 26–40

111 Abu-Elanien, A.E.B., Salama, M.M.A., Ibrahim, M.: ‘Determination of transformer health condition using artificial neural networks’. Proc. of IEEE Innovations in Intelligent Systems and Applications, 2011

112 GE Energy: ‘Determination of health index for aging transformers in view of substation asset optimization’, 2010

113 Ashkezari, A.D., Ma, H., Saha, T.K., *et al.*: ‘Investigation of feature selection techniques for improving efficiency of power transformer condition assessment’, *IEEE Trans. Dielectr. Electr. Insul.*, 2014, **21**, (2), pp. 836–844

114 Ashkezari, A.D., Ma, H., Saha, T.K., *et al.*: ‘Application of fuzzy support vector machine for determining the health index of the insulation system of in-service power transformers’, *IEEE Trans. Dielectr. Electr. Insul.*, 2013, **20**, (3), pp. 965–973

115 Morton, K.: ‘Asset management in the electricity supply industry’, *Power Eng. J.*, 1999, **13**, (5), pp. 233–240

116 Abiri-Jahromi, A., Fotuhi-Firuzabad, M., Abbasi, E.: ‘An efficient mixed-integer linear formulation for long-term overhead lines maintenance scheduling in power distribution systems’, *IEEE Trans. Power Deliv.*, 2009, **24**, (4), pp. 2043–2053

117 Carer, P.: ‘Probabilistic methods used in asset management for MV electrical equipment at EDP’. Proc. of Int. Conf. on Probabilistic Methods Applied to Power Systems, 2006

118 Haghifam, M.-R., Akhavan-Rezai, E., Fereidunian, A.: ‘An asset management approach to momentary failure risk analysis on MV overhead lines’. Proc. of Int. Conf. on Probabilistic Methods Applied to Power Systems, 2010

119 Bloom, J.A., Feinstein, C., Morris, P.: ‘Optimal replacement of underground distribution cables’. Proc. of IEEE Power Systems Conf. Exposition, 2006

120 Mackinlay, R., Walton, C.: ‘Diagnostics for MV cables and switchgear as a tool for effective asset management’. Proc. of Int. Conf. on Exhibition on Electricity Distribution, 2001

121 Lindquist, T., Bertling, L., Eriksson, R.: ‘A feasibility study for probabilistic modeling of aging in circuit breakers for maintenance optimization’. Proc. of Int. Conf. on Probabilistic Methods Applied to Power Systems, 2004

122 Hoidalen, H.K., Runde, M.: ‘Continuous monitoring of circuit breakers using vibration analysis’, *IEEE Trans. Power Deliv.*, 2005, **20**, (4), pp. 2458–2465

123 Natti, S.: ‘Risk based maintenance optimization using probabilistic maintenance quantification models of circuit breaker’ (Texas A&M University, 2008)

124 Lin, P.-C., Gu, J.-C., Yang, M.-T.: ‘An intelligent maintenance model to assess the condition-based maintenance of circuit breakers’, *Int. Trans. Electr. Energy Syst.*, 2014, **25**, (10), pp. 2376–2393

125 Yoon, K.T., Teo, D.S.A.: ‘Controlling and monitoring Singapore’s underground grid’, *IEEE Comput. Appl. Power*, 1999, **12**, (4), pp. 23–29

126 Kostic, T.: ‘Asset management in electrical utilities: how many facets it actually has’. Proc. of IEEE Power Engineering Society General Meeting, 2003

127 Yuen, C., Kostic, T.: ‘IT applications for asset management: disturbance records as support for AM processes’. Proc. of IEEE PowerTech Conf., 2003

128 Abeygunawardane, S.K., Jirutitijaroen, P.: ‘A realistic maintenance model based on a new state diagram’. Proc. of Int. Conf. on Probabilistic Methods Applied to Power Systems, 2010

129 Lucio, J.C.M., Teive, R.C.G.: ‘Fuzzy causal maps for asset management: an approach for problem structuring and multi-criteria evaluation in electrical utilities’. Proc. of IEEE PowerTech Conf., 2007

130 Jayakumar, A., Asgarpoor, S.: ‘Maintenance optimization of equipment by linear programming’. Proc. of Int. Conf. on Probabilistic Methods Applied to Power Systems, 2004

131 Tanaka, H., Magori, H., Niimura, T., *et al.*: ‘Optimal replacement scheduling of obsolete substation equipment by branch & bound method’. Proc. of IEEE Power and Energy Society General Meeting, 2010

132 Lindquist, T.M., Bertling, L., Eriksson, R.: ‘Estimation of disconnector contact condition for modelling the effect of maintenance and ageing’. Proc. of IEEE PowerTech Conf., 2005

133 Lindquist, T.M., Bertling, L., Eriksson, R.: ‘A method for age modeling of power system components based on experiences from the design process with the purpose of maintenance optimization’. Proc. of Int. Conf. on Reliability and Maintainability Symp., 2005

134 Feng, Z., Ajjarapu, V., Maratukulam, D.J.: ‘A practical minimum load shedding strategy to mitigate voltage collapse’, *IEEE Trans. Power Syst.*, 1998, **13**, (4), pp. 1285–1291

135 Feng, Z., Ajjarapu, V., Maratukulam, D.J.: ‘A comprehensive approach for preventive and corrective control to mitigate voltage collapse’, *IEEE Trans. Power Syst.*, 2000, **15**, (2), pp. 791–797

136 Feng, Z., Ajjarapu, V., Long, B.: ‘Identification of voltage collapse through direct equilibrium tracing’, *IEEE Trans. Power Syst.*, 2000, **15**, (1), pp. 342–349

137 Echavarren, F.M., Lobato, E., Rouco, L.: ‘A corrective load shedding scheme to mitigate voltage collapse’, *Electr. Power Energy Syst.*, 2006, **28**, (1), pp. 58–64

138 Otomega, B., Glavic, M., Van Cutsem, T.: ‘A two-level emergency control scheme against power system voltage instability’, *Control Eng. Pract.*, 2014, **30**, pp. 93–104

139 Voumvoulakis, E.M., Hatziargyriou, N.D.: ‘A particle swarm optimization method for power system dynamic security control’, *IEEE Trans. Power Syst.*, 2010, **25**, (2), pp. 1032–1041

140 Voumvoulakis, E.M., Hatziargyriou, N.D.: ‘Decision trees-aided self-organized maps for corrective dynamic security’, *IEEE Trans. Power Syst.*, 2008, **23**, (2), pp. 622–630

141 Genc, I., Diao, R., Vittal, V., *et al.*: ‘Decision tree-based preventive and corrective control applications for dynamic security enhancement in power systems’, *IEEE Trans. Power Syst.*, 2010, **25**, (3), pp. 1611–1619

142 Krishnan, V., McCalley, J.D., Henry, S., *et al.*: ‘Efficient database generation for decision tree based power system security assessment’, *IEEE Trans. Power Syst.*, 2011, **26**, (4), pp. 2319–2327

143 He, M., Zhang, J., Vittal, V.: ‘Robust online dynamic security assessment using adaptive ensemble decision-tree learning’, *IEEE Trans. Power Syst.*, 2013, **28**, (4), pp. 4089–4098

144 Liu, C., Sun, K., Rather, Z.H., *et al.*: ‘A systematic approach for dynamic security assessment and the corresponding preventive control scheme based on decision trees’, *IEEE Trans. Power Syst.*, 2014, **29**, (2), pp. 717–730

145 Xu, Y., Dong, Z.Y., Zhang, R., *et al.*: ‘A decision tree-based on-line preventive control strategy for power system transient instability prevention’, *Int. J. Syst. Sci.*, 2014, **45**, (2), pp. 176–186

146 Gong, B., Hiskens, I.: ‘Two-stage model predictive control for voltage collapse prevention’. Proc. of IEEE North American Power Symp., 2008

147 Church, C., Morsi, W.G., El-Hawary, M.E., *et al.*: ‘Voltage collapse detection using ant colony optimization for smart grid applications’, *Electr. Power Syst. Res.*, 2011, **81**, (8), pp. 1723–1730

148 Singh, A., Chauhan, S.: ‘Security monitoring against voltage collapse through ant colony system’. Proc. of IEEE National Power Systems Conf., 2014

149 Ayana, K., Kılıç, U., Baraklı, B.: ‘Chaotic artificial bee colony algorithm based solution of security and transient stability constrained optimal power flow’, *Electr. Power Energy Syst.*, 2015, **64**, (1), pp. 136–147

150 Kucuktezcan, C.F., Genc, V.I.: ‘A new dynamic security enhancement method via genetic algorithms integrated with neural network based tools’, *Electr. Power Syst. Res.*, 2012, **83**, (1), pp. 1–8

151 Arya, L.D., Singh, P., Titare, L.S.: ‘Differential evolution applied for anticipatory load shedding with voltage stability considerations’, *Electr. Power Energy Syst.*, 2012, **42**, (1), pp. 644–652

152 Xu, Y., Dong, Z.Y., Luo, F., *et al.*: ‘Parallel-differential evolution approach for optimal event-driven load shedding against voltage collapse in power system’, *IET Gener. Transm. Distrib.*, 2014, **8**, (4), pp. 651–660

153 Arandian, B., Hooshmand, R.A., Gholipour, E.: ‘Decreasing activity cost of a distribution system company by reconfiguration and power generation control of DGs based on shuffled frog leaping algorithm’, *Electr. Power Energy Syst.*, 2014, **61**, pp. 48–55

154 Kucuktezcan, C.F., Genc, V.I.: ‘Preventive and corrective control applications in power systems via big bang–big crunch optimization’, *Electr. Power Energy Syst.*, 2015, **67**, pp. 114–124

155 McCalley, J., Asgarpoor, S., Bertling, L., *et al.*: ‘Probabilistic security assessment for power system operations’. Proc. of IEEE Power Engineering Society General Meeting, 2004

156 CIGRE WG C4.601: ‘Review of the current status of tools and techniques for risk-based and probabilistic planning in power systems’, 2010

157 Nordgård, D.E., Uhlen, K., Bakken, B.H., *et al.*: ‘Implementation of a probabilistic security assessment tool for determination of power transfer limits’. CIGRE Session, 2002

158 Rios, M., Kirschen, D.S., Jayaweera, D., *et al.*: ‘Value of security: modeling time-dependent phenomena and weather conditions’, *IEEE Trans. Power Syst.*, 2002, **17**, (3), pp. 543–548

159 Preece, R., Milanovic, J.: ‘Probabilistic risk assessment of rotor angle instability using fuzzy inference systems’, *IEEE Trans. Power Syst.*, 2015, **30**, (4), pp. 1747–1757

160 Ding, Y., Wang, P., Lisnianski, A.: ‘Optimal reserve management for restructured power generating systems’, *Reliab. Eng. Syst. Saf.*, 2006, **91**, pp. 792–799

161 Ciapessoni, E., Cirio, D., Grillo, S., *et al.*: ‘An integrated platform for power system security assessment implementing probabilistic and deterministic methodologies’, *IEEE Syst. J.*, 2013, **7**, (4), pp. 845–853

162 Tuinema, B.W., Gibescu, M., Kling, W.L.: ‘Availability evaluation of offshore wind energy networks within the Dutch power system’. Proc. of IEEE Young Researchers Symp.: Smart Sustainable Power Delivery, 2010

163 Vefsnmo, H., Kjolle, G., Jakobsen, S.H., *et al.*: ‘Risk assessment tool for operation: from threat models to risk indicators’. Proc. of IEEE PowerTech Conf., 2015