On future of robust control in smart grids

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On Future of Robust Control in Smart Grids

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Abstract: **The characteristics of smart grids introduce robust control techniques as more powerful and suitable control tools for control synthesis/analysis problems in these grids. However, there are some important challenges in application of robust control theorems in new power systems. Here, two main challenges are discussed and probable solutions are given to fill the existing gap between the power of robust control theorems and smart grid control designs.**

Keywords: Robust control, Wide-area control, Smart grid, Model identification, Order reduction.

I. Introduction

Automatic control design has been one of major subjects in real-world power grids design/operation and is becoming much more significant today in accordance with increasing size, changing structure, emerging distributed generators (DGs) and renewable energy sources (RESs), uncertainties and complexity of modern power networks known as smart grids. A major challenge in smart grids is to integrate computing, communication and control into appropriate levels of real-world system operation and control.

Increase of size and complexity, increase of diversity in generation/load, variable nature of RESs, and continues change of structure (uncertainty) are known as some important characteristics of new power grids. It seems that conventional controls are not more effective, and may fail to meet the specified control objectives in new environment. On the other hand, the above characteristics introduce robust control techniques as powerful and more suitable control tools for stability analysis and control synthesis problems in modern power grids (smart grids).

Maintain robust stability and/or robust performance in the presence of a wide range of noises, disturbances and uncertainties is the main objective of well-known robust control techniques such as H_2, $H\infty$, mixed $H_2/H\infty$, structured singular value (μ), Kharitonov theorem, quantaitive feedback theorem (QFT) and model predictive control (MPC). Selection of robust control technique for a given control synthesis problem depends on several items including type of control problem, control objectives and case study.

Application of linear robust control methods in new power systems is not straightforward. Needing to obtain linearized dynamical model for the wide-area power grids which is very difficult, as well as high-order and complexity of resulted controllers are two main challenges in this direction. The present speech is focused on these challenges and relevant probable solutions.

II. Need To Dynamic Model

As shown in Fig. 1, similar to the most control methods, in the synthesis procedure of robust controls, the dynamic model of the controlled system is required. For a power grid in the new environment, obtaining this model due to size, complexity and variability of the grid is difficult and even impossible.

Measurement-based low-order model estimation can be utilized in modern power systems worldwide, opening new way for application of robust control methodologies. Fig. 2 shows a new scheme for control synthesis using wide-area monitoring-based methods. For example, for designing of wide-area damping control, instead of whole dynamic model, one can simply identify a second order oscillation model for the dominant oscillation mode using voltage phasors of two measurement sites.

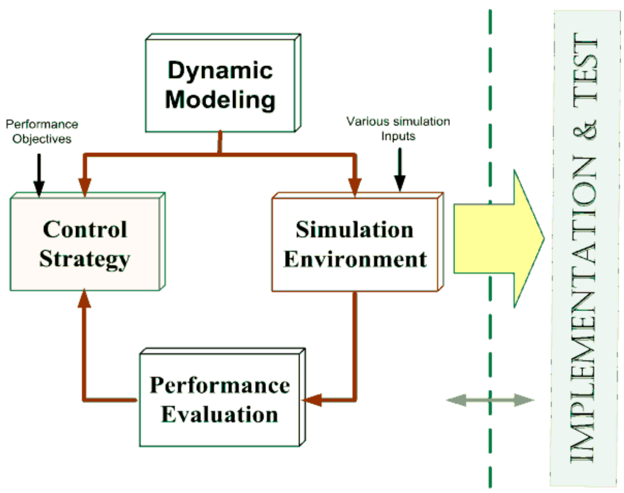

Fig.1 Control synthesis procedure

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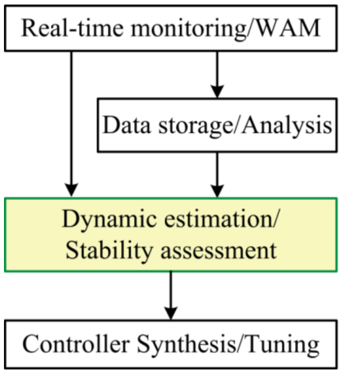

Fig. 2. Measurement-based control synthesis

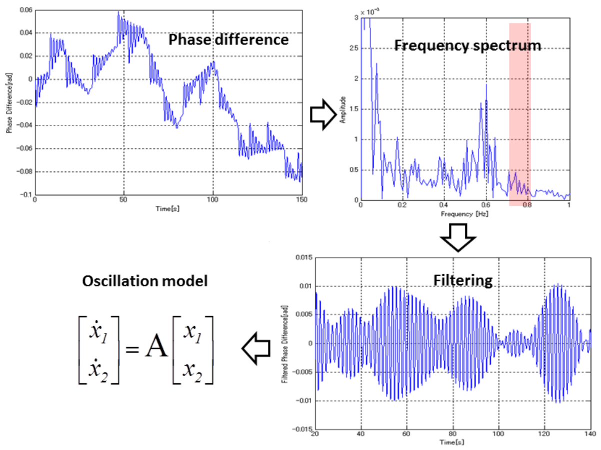

Fig. 3. Oscillation model estimation using phasor measurement

This method is descriptively shown in Fig. 3, and extensively explained in [1].

III. Complexity of Controllers

In practice, many control systems usually track different control objectives such as stability, disturbance attenuation and reference tracking with considering practical constraints, simultaneously. In the power grid applications, it is usually desirable to meet all the specified goals using controllers with simple structures. Since, practically conventional controllers are commonly designed based on experiences, classical and trial-and-error approaches, they are incapable of obtaining desirable dynamical performance to capture all design objectives and specifications for a wide range of operating conditions and various disturbances.

It is significant to note that because of using simple structure, pertaining to a low-order control synthesis for dynamical systems in the presence of strong constraints and tight objectives are few and restrictive. Under such conditions, the control synthesis process may not approach to a strictly feasible solution. Therefore, most of robust control approaches suggest complex state-feedback or high-order dynamic controllers. Moreover in the most of proposed approaches, a single performance criterion has been used to evaluate the robustness of resulted control systems.

This speech addresses some systematic, fast and flexible algorithms to design of low order robust controllers applicable in various control level/type of smart grids. The developed strategies attempt to invoke the strict conditions and bridge the gap between the power of robust control theorems and reality of smart grid controls.

Fig. 4 shows the main steps of the developed algorithms. In the proposed methodology, after selection of a proper robust control theorem to find an optimal performance index (γ), the given control design is reduced to a more simple control synthesis (e.g, static output feedback control). Then the optimal controller gains are found out using an iterative linear matrix inequalities (ILMI) algorithm such that the specified optimal performance index to be closely tracked. To illustrate the effectiveness of the proposed control strategies, several examples with detailed explanations are given in [2].

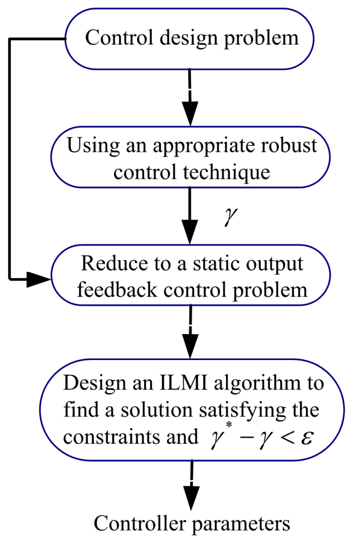

Fig. 4. A synthesis framework for designing robust controllers with simple structures.

IV. Conclusion

In this speech, the capability of robust control to solve various power system control problems is emphasized. The most important challenges in front of application of well-known robust control techniques in modern power grids (smart grids) are discussed. Finally, to illustrate the presented issues, several synthesis examples are reviewed.

References

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[2] H. Bevrani, *Robust power system frequency control*, Springer, NY, 2 Ed., July 2014.