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Predictive Control of Power Converter and Electrical Drive

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Abstract: *Controlling power electronic converters is a very appealing use of model predictive control (MPC). In order to describe the current state of this control method and analyze the new trends and challenges it brings when used in power electronic systems, the goal of this study is to present and debate the most recent breakthroughs in MPC for power converters and drives. The prediction model, the cost function, and the optimization algorithm are the three crucial components of MPC methods, which are revisited in this study together with the MPC operating principle. The report provides information on the many solutions suggested by the academic and industrial groups while summarizing the most recent research on these components*

Keywords: Power Factor Controller, Boost Converter, Current Quality, Power Electronics Circuits.

I. INTRODUCTION

For more than three decades, model predictive control (MPC) has been the subject of research and development.
Predictive control was initially developed in the process industry, but a very pioneering and early work suggested that it be utilized in power electronics. Thanks to advancements in microprocessor technology, it has recently been suggested and investigated as a potential replacement for the control of power converters and drives. MPC has a number of benefits. It can be applied to a range of processes, is easy to implement in multivariable systems, and provides a quick dynamic reaction, for example. In addition, it makes it simple to include constraints and nonlinearities in the control law, and it can accommodate nested control loops in only one loop.

Power electrical applications in particular necessitate control responses in the range of tens to hundreds of microseconds to function properly. Nevertheless, it is common knowledge that MPC requires more processing than other control schemes. Due to this, the most of the study on this topic during the early stages of MPC for power electronic systems.

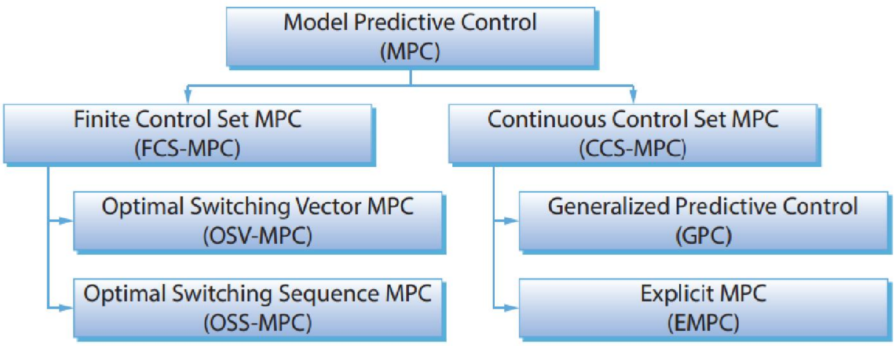

Figure. 1. Classification of MPC strategies applied to power converters and drives.

The purpose of this study is to review the existing situation and examine the most recent developments in the use of MPC for drives and power converters. Thus, the paper discusses potential future trends as well as the current developments and difficulties of MPC for power electronic applications.

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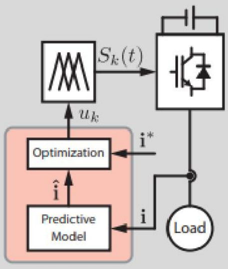
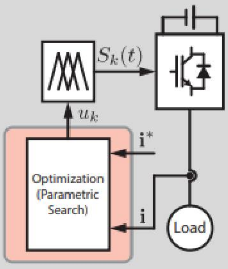
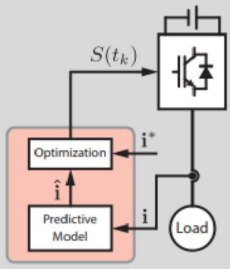
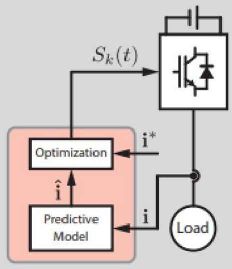
TABLE I: MOST USED MPC STRATEGIES FOR POWER ELECTRONICS APLICATIONS

Item Description	GPC	EMPC	OSV-MPC	OSS-MPC
Block diagram				
Modulator	SVM or PWM	SVM or PWM	Not required	Not required
Fixed switching frequency	Yes	Yes	No	Yes
Optimization	Online	Offline (Parametric search)	Online	Online
Constraints	Can be included but increases the computational cost	yes	yes	yes
Long prediction horizon	Yes	Yes	Can be used but requires special search algorithm	Can be used but requires special search algorithm
Formulation	Complex	Complex	Very intuitive	Intuitive
References	[13], [14]	[15], [16]	[17], [18]	[19], [20]

II. MODEL PREDICTIVE CONTROL OPERATING PRINCIPLE

An explicit model of the system to be controlled is used by the MPC family of controllers. MPC typically establishes the control action by minimizing a cost function that captures the desired system behavior. This cost function makes a comparison between the anticipated system output and a standard. The system model is used to compute the anticipated outputs. The MPC controller typically calculates a control action sequence for each sample time that minimizes the cost function, but only the first piece of this sequence is applied to the system.

The MPC algorithm is repeated in a receding horizon form at each sample period, providing a feedback loop and potential robustness with respect to system uncertainties even though MPC controllers solve an open-loop optimum control problem.

A fundamental MPC method with a prediction horizon of 1 applied to the current control of a voltage source inverter (VSI) with an output RL load is illustrated [17] to demonstrate the usage of MPC for power electronics. This control strategy's fundamental block architecture is shown in Fig. 1, where the reference and forecast currents at instant k + 2 are employed to make up for the delay in the digital implementation [21]. The following actions are taken by the algorithm, which is repeated for each sampling time:

1) The optimal control action $S(t_k)$ computed at instant $k-1$ is applied to the converter.

2) Measurement of the current i_k is taken at instant k. The reference current i^*_{k+2} for instant k + 2 is also defined.

3) The prediction model of the system is used to make a prediction of the current value $\hat{i}_{k+2}$ at instant k + 2.

4) A cost function is evaluated using i^*_{k+2} and $\hat{i}_{k+2}$. The optimal control action $S(t_{k+1})$ to be applied at instant k+ 1 is chosen as the one that minimizes the cost function's value.

The prediction model, cost function, and optimization algorithm are the three essential components of every MPC approach, according to an examination of MPC algorithms used to optimize power converters and drives. All of these areas have seen research attempts, and a number of issues and constraints have been discovered. Some of these have been resolved by recent study, while others remain unresolved problems that need to be looked at. The most significant areas of research concern.

- Prediction model discretization.
- Frequency spectrum shaping.
- Cost function design.

- Reduction of computational cost.
- Increasing prediction and control horizon.
- Stability and system performance design.

The most recent research for all of these topics will be addressed in the following sections.

III. PREDICTION MODEL

The quality of the prediction model, which depends on the particular application under consideration, has an impact on MPC performance. To reduce the impacts of commutations or supply distortions, the majority of power converters are connected to the load through passive filters. It is possible to employ first-order passive filters made up of an inductor and a parasitic resistor. But high order passive filters like LC or LCL are also used in VSC-AFE, MV motor drives, VSC-UPS matrix converters, and other devices.

Any passive filter architecture can be used with MPC as long as the mathematical model is included in the prediction model.

Most frequently, digital hardware platforms like DSPs or FPGAs are used to build MPC algorithms. The system's prediction model must be discretized as a result.

The discretization for linear systems is straightforward and can be carried out as described. However, non-linear systems demand a more sophisticated strategy. Several discretization methods are defined by a trade-off between model quality and complexity, with Euler approximation and Taylor series expansion being the most popular. Another method involves discretizing the system using a one- or multi-step Euler approximation in the first phase. The resulting discretization error is therefore expressly required to be taken into account when the predictive controller is implemented.

IV. COST FUNCTION ISSUES

The MPC strategy's cost function specifies the intended system behavior. It contrasts the expected and reference values to do this. The cost function can have any shape, but generally speaking, it can be expressed as

$$g = \sum_{\ell=k+1}^{k+N_p} \tilde{\mathbf{x}}_\ell^T Q \tilde{\mathbf{x}}_\ell + \sum_{r=k}^{k+N_c-1} \mathbf{u}_r^T R \mathbf{u}_r$$

where ˜xℓ = ˆxℓ − x ∗ ℓ is a vector in which each component represents the difference between the predicted, xˆj,ℓ, and the reference, x ∗ j,ℓ, values for any variable xj at instant ℓ, ur is a vector of control inputs ui at instant r, and Np and Nc are the prediction and control horizons, respectively.

MPC allows one to solve Multiple Input and Multiple Output (MIMO) problems. Therefore, ˜xℓ ∈ R m, ur ∈ R n and Q ∈ R mxm, R ∈ R nxn are matrices representing weighting factors. When Q and R are diagonal, then (1) can be expressed as

$$g = \sum_{\ell=k+1}^{k+N_p} \sum_{j=0}^{m-1} \lambda_j \left(\hat{x}_{j,\ell} - x_{j,\ell}^*\right)^2 + \sum_{r=k}^{k+N_c-1} \sum_{i=0}^{n-1} \lambda_i \left(u_{i,r}\right)^2$$

where λj and λi are the weighting factors associated to the variable xj and control action ui , respectively. Although, (2) is used more frequently, both (1) and (2) are valid expressions. Designing g is not an easy task. The variables xj included in g depend on the application and choosing the weighting factors affects the system's performance and stability, it can therefore be seen as a tuning procedure. Both issues have been studied by the research community and will be addressed in the following sections.

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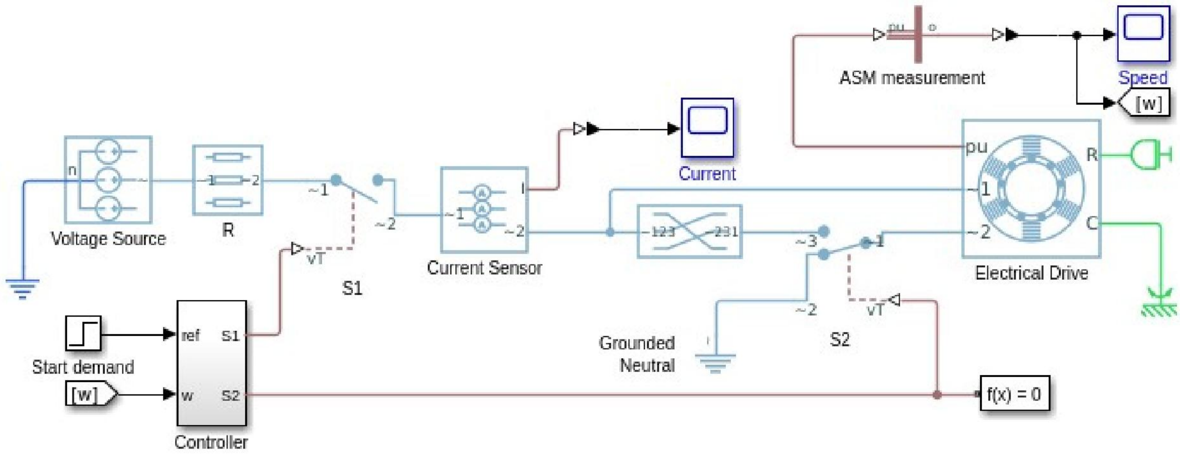
V: MATLAB SIMULATION & RESULTS

1: MODEL AND SIMULATION RESULTS FOR PREDICTIVE CONTROL OF POWER CONVERTER:



2: MODEL AND SIMLATION RESULTS OF COTROLLER

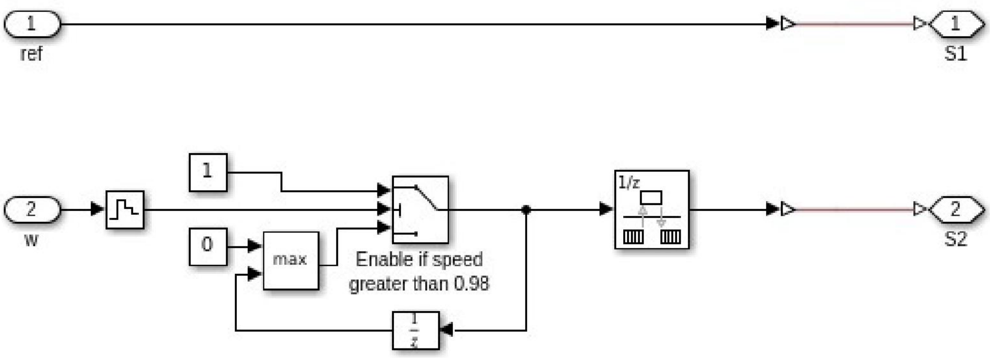


FIGURE: ACTIVE & REACTIVE POWER

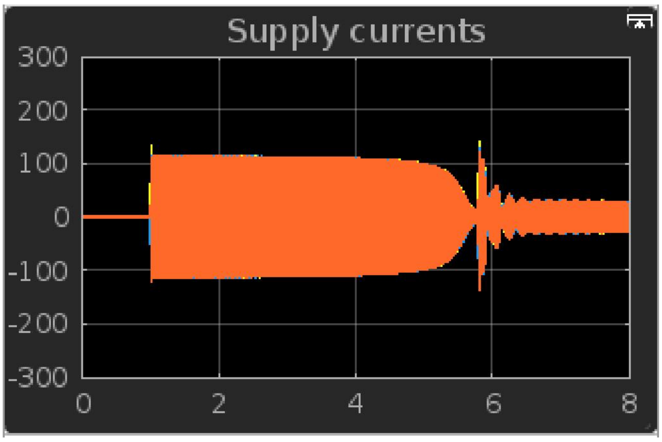


Figure. Current Flow

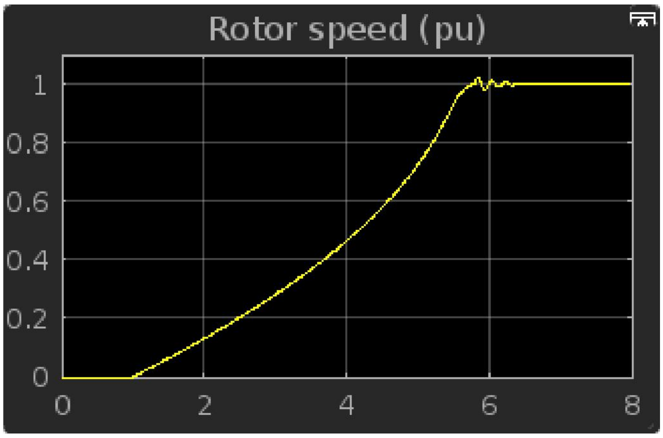


Figure. Motor Speed

VI: CONCLUSION

For managing power electronic applications, model predictive control (MPC) is a very appealing option. The most recent developments and trends in MPC for power converters and drives are presented in this study. After reviewing the MPC's working principle, it can be said that three crucial components—the prediction model, the cost function, and the optimization algorithm—are necessary for successful MPC implementation. The scientific and business communities have looked into a number of issues connected to these areas. The selection of the cost function, the design of the weighting factors, the reduction of the computing cost, and the expansion of prediction horizons are the most important challenges.The paper introduces the most significant MPC advancements applied to power converters and drives, summarizing several solutions for these issues that have been offered in the literature survey skin cancer detection

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BIOGRAPHY

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