optimization problem

MPC OUTPUT AND INPUTS

FS-MPC algorithm accepts 7 input values: time (t),

filter currents (if α, if β), capacitor voltage deviations (Δvc α,

Δvc β), optimum voltage vector from previous sampling period

x(k−1), load resistance (Rload) and calculates 3 output values:

reference values (vref α, vref β), and future optimum switching

combination x(k + 1). The reference values vref αβ are not

used in the inputs because the two values are coupled and to

keep this dependency it is more convenient to use time vector

as an input value. They are calculated using two sine wave

equations with a 120◦ phase shift and the input value of the

time vector t. \cite{Imitation_learning}

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COST FUNCTION

THEN, DERIVATIVES ARE NEEDED AND DRAWING, AND NEW COST FUNCTION WITH EVERYTHING AS IN 1)))))

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In [30], the conventional Euclidean distance-based CF in the

αβ frame was used:

gcon = vf α ∗ − vf α2 + vf β ∗ − vf β2

It aims to minimize the

Euclidean distance at every sampling instant.

\cite{Dragicevic2018}

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To determine which of the

control actions is to be selected, a decision or cost function fg

can be defined, usually dependent on the desired reference value and the predictions $g_i = f_g\{x*(t_{k+1}), x_{pi}(t_{k+1})\}$, for

$i = 1, \ldots, n$. Note that the future reference value is needed

$x*(t_{k+1})$, which can be assumed to be equal to the actual

value $x*(t_k)$, since T_s is sufficiently small compared with the

dynamic behavior of the system, and thus, the reference can

be considered constant over T_s. If needed for highly dynamic

systems, the future reference value $x*(t_{k+1})$ can be estimated

via appropriate extrapolation methods. (as in ours)

\cite{Kouro2009}

A typical example for would be the absolute error between the predictions and

the reference $g_i = |x*(t_{k+1}) - x_{pi}(t_{k+1})|$ /IN OUR CASE IS NOT ABSOLUTE, IS SQUARED WHICH TAKES ABSOLUTE VALUE AND ALSO MAKES BIG DIFFERENCES BIGGER AND SMALL DIFFERENCES SMALLER). The evaluation of

the cost function with the n predictions will lead to n different

costs. Naturally, the control action leading to the minimum cost

($\min\{g_i\}$, for $i = 1, \ldots, n$) is selected to control the system \cite{Kouro2009}

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where $\bar{v}*$

$f = v_{f\alpha}* + jv_{f\beta}*$ is the voltage reference vector, !

is the reference frequency and λ_d is the weighting factor of

the additional current reference term. This term was proposed

in [16] for improving the steady state performance of the

algorithm and the weighting factor can be selected using the

ANN approach in [17]. Table I shows system parameters used

in the control algorithm \cite{Imitation_learning}.

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INTRO TO THIS FIGURE

A simplified control block diagram and the corresponding

algorithm for the real-time implementation of FCS-MPC are

shown in Figs. 2 and 3, respectively, considering a generic system variable x(t). It is worth mentioning that this control

method is not limited to a single variable; on the contrary, multiple variables, system constraints, perturbations, saturations,

and, basically, every characteristic that can be mathematically

modeled and measured can be included in the predictive model

and cost function. This is the basis of the great flexibility

and control potential that can be achieved with FCS-MPC.

Moreover, the fact that power converters have a reduced and

limited number of switching states (or control set) makes this

method feasible to implement with present-day available microprocessing resources. Since only a discrete model of the system

is necessary, rather than approximated linear models together

with control system design theory and modulation algorithms,

a simpler and more direct design and implementation of the

controller can be achieved. \cite{Kouro2009}

MPC EXPLANATION FIGURE

Based on the example shown in Fig. \ref{fig:MPC_explanation}, the predicted

value x

p3(tk+1) is the closest to the reference x∗(tk+1); hence,

S3 is selected and applied in t = tk. Following the same

criterion, S2 is selected and applied in t = tk+1. However, the

ideal theoretical case in which the variables can be measured,

predicted, and controlled instantly in t = tk is not realizable in

real-time applications. Nevertheless, this problem can be overcome if a two-step-ahead prediction is considered, as shown

in Fig. 1(b), in which the control action to be applied in the

following sample time S(tk+1) is determined. This way, a complete sample period Ts is available to perform the algorithm.

Naturally, the sample period Ts has to be greater than the

measurement, computation, and actuation times added together.

Assume that on a sample time tk, a measurement x(tk) is made and the previously computed control action S(tk) is

applied. With this information and the system model, a first

prediction can be made to obtain the future value x(tk+1)

(this is the first step prediction). Now, from the predicted value

x

p(tk+1), the FCS-MPC algorithm is performed for n possible control actions, leading to one optimal selection S(tk+1)

(this is the second step prediction). Both predictions are performed during the first sample period, and then, at t = tk+1,

the optimal selected control action S(tk+1) is applied, while

x(tk+1) is measured to perform the algorithm again. As shown

in the example in Fig. 1(b), there is only one prediction for

the first step, given by the applied control action S(tk) = S3

determined in the previous execution of the algorithm while S(tk+1) = S2 is selected from the n predictions for the

second step. \cite{Kouro2009}

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1)))))) WHY DERIVATIVES

Although this may result in satisfactory performance for first

order systems, coupling between the state variables makes it

somewhat unsuitable for second order ones. The reason is that

the controlled variable in first-order systems (i.e., converter

side inductor current in the L filter) can be directly regulated

by the control input, allowing an instantaneous change of its

derivative at a particular sampling instant. On the contrary,

capacitor voltage in the second-order LC filter configuration

can only be regulated indirectly through the inductor current. As

respective current cannot change instantaneously its value, the

capacitor voltage correspondingly cannot change its derivative

instantaneously.

Therefore, by involving exclusively the capacitor voltage error in the CF, as in (21), no respect is given to its derivative. The

result is that the minimal magnitude error will often be achieved

at a cost of having voltage trajectory pointing significantly away

from the reference trajectory. This causes intractable voltage deviations in intersampling periods which often lead to unfavorable starting points at future time instants, ultimately resulting

in high total harmonic distortion (THD) in the measured voltage

signal.

This phenomenon is illustrated in Fig. 4, where the exemplary propagation of capacitor voltage is shown. It can be seen

from the figure that, although the transition from the initial time

step t1 to step t2 with control input u = 2 leads to the smallest

error at the sampling instance t2, it also results in a significant

deviation of voltage trajectory heading from the reference heading. Therefore, the capacitor voltage will continue to decrease

rapidly regardless of the input applied at time instant t2, resulting in a large oscillations around the reference and consequently

a large THD. \cite{Dragicevic2018}

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Assuming the model of the system to be accurate enough, FS-MPC often yields better stationary and transient response than linear closed-loop control structures.

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we do not need to use modulation this controller alredy cretaes the signals to the switches

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In addition, other converter topologies, drives, and applications are

addressed to show the flexibility and potentiality of FCS-MPC

\cite{Kouro2009}

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%FS-MPC has, however, an important shortcoming. When predicting the values of states for more than a single step ahead, the number of calculations to be performed increases exponentially.

%The exponentially increasing computational requirements of FS-MPC means that it is often not possible to implement such an algorithm that is able to run in a time short enough to guarantee adequate performance while using a prediction window larger than very few steps ahead. For multi-level and multi-cell converters, for which many more possible states exist than for a six-switch inverter, this problem is further accentuated.

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MPC has several advantages, such as the easy inclusion of nonlinearities and constraints. This scheme has

few applications in power converter control and drives due to

the high amount of calculations needed in order to solve the

optimization problem online, which is incompatible with the

small sampling times used in converter control. One solution in

order to reduce the calculation time is to solve the optimization

problem offline, as presented in [27], where MPC is implemented as a search tree and the calculation time is reduced,

making it possible to use the MPC in drive control. Another

solution is the use of Generalized Predictive Control (GPC)

[28], where the optimization is solved analytically, obtaining

a linear controller. Nevertheless, with GPC, it is very difficult

to include system constraints and nonlinearities. \cite{Kouro2009}.

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MPC forces to commutate the optimal choice for each T_s, this sometimes means to continue with the previous state and do not commutate that sampling period, hence the average switching frequency is variable. drawback: spread current spectrum.

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COMPARACION SVM CON MPC

Fijando Ts, switchea menos que SVM porque SVM cambia 6 veces por Ts, sin embargo, MPC no elige la pata optima que cambiar, sino que elige el estado, de forma que cambiar de un estado a otro puede incluir cambiar varias ptas a la vez, un maximo de 3. de esta forma, MPC cambiaria de 0 a 3 switches respecto a los 6 que cambiar de forma continua por Ts SVM.