Let

$$f_*(X) = \mathbb{E}Y|X$$

be the regression function and

$$\overline{f}(X) = \mathbb{E}_{\mathcal{D}}\hat{f}(X)$$

be the average over the training distribution of the procedure $\hat{f}$. Then

$$
\begin{aligned}
R(\hat{f}) &:= \mathbb{E}_{\mathcal{D},Z}(Y - \hat{f}(X))^2 && (1)\\
&= \mathbb{E}_{\mathcal{D},Z}(Y - f_*(X) + f_*(X) - \overline{f}(X) + \overline{f}(X) - \hat{f}(X))^2 && (2)\\
&= \mathbb{E}_{\mathcal{D},Z}(Y - f_*(X))^2 + \mathbb{E}_{\mathcal{D},Z}(f_*(X) - \overline{f}(X))^2 + \mathbb{E}_{\mathcal{D},Z}(\overline{f}(X) - \hat{f}(X))^2 + && (3)\\
&\quad \mathbb{E}_{\mathcal{D},Z}(Y - f_*(X))(f_*(X) - \overline{f}(X)) + \mathbb{E}_{\mathcal{D},Z}(f_*(X) - \overline{f}(X))(\overline{f}(X) - \hat{f}(X)) + && (4)\\
&\quad + \mathbb{E}_{\mathcal{D},Z}(Y - f_*(X))(\overline{f}(X) - \hat{f}(X)) && (5)\\
&= \sigma^2 + \mathrm{B} + \mathrm{V} + && (6)\\
&\quad (I) + (II) + && (7)\\
&\quad + (III) && (8)
\end{aligned}
$$

Both σ^2 and B do not depend on $\mathcal{D}$, so the integration is only with respect to Z. Hence

$$\sigma^2 = \mathbb{E}_Z(Y - f_*(X))^2 = \mathbb{E}_X\mathbb{E}_{Y|X}(Y - f_*(X))^2.$$

Also, there is no Y in B, hence we are only integrating with respect to the marginal of X

$$\mathbb{E}_{\mathcal{D},Z}(f_*(X) - \overline{f}(X))^2 = \mathbb{E}_X(f_*(X) - \overline{f}(X))^2 = \int (f_*(X) - \overline{f}(X))^2 d\mathbb{P}_X,$$

and similarly

$$\mathbb{E}_{\mathcal{D},Z}(\overline{f}(X) - \hat{f}(X))^2 = \mathbb{E}_Z\mathbb{V}\hat{f}(X) = \int \mathbb{V}\hat{f}(X) d\mathbb{P}_X.$$

The cross terms can be seen to be zero

$$(I) = \mathbb{E}_{\mathcal{D},Z}(Y - f_*(X))(f_*(X) - \overline{f}(X)) = \mathbb{E}_{\mathcal{D}}\mathbb{E}_X(f_*(X) - \overline{f}(X))\mathbb{E}_{Y|X}(Y - f_*(X)) = 0,$$

$$(II) = \mathbb{E}_{\mathcal{D},Z}(f_*(X) - \overline{f}(X))(\overline{f}(X) - \hat{f}(X)) = \mathbb{E}_Z(f_*(X) - \overline{f}(X))\mathbb{E}_{\mathcal{D}}(\overline{f}(X) - \hat{f}(X)) = 0,$$

and

$$(III) = \mathbb{E}_{\mathcal{D},Z}(Y - f_*(X))(\overline{f}(X) - \hat{f}(X)) = \mathbb{E}_{\mathcal{D}}\mathbb{E}_X(\overline{f}(X) - \hat{f}(X))\mathbb{E}_{Y|X}(Y - f_*(X)) = 0.$$